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Reconnaissance Evaluation of Water Quality - Salinity Loading Relationships of Intermittent Flow Events in a Desert Environment, Las Vegas, Nevada

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Final Report

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ABSTRACT

The Bureau of Land Management (BLM), in recognition of the need to identify the mechanisms and significance of salinity loading from arid ephemeral drainages in the Lower Colorado River Basin, sponsored this reconnaissance effort. The principal project objectives were to sample the water quality of flash flood events over a two-year period in selected drainage basins and relate field data to the probable type and magnitude of salinity loading that ungaged arid basins could contribute to the Colorado River. Remote water samplers and eolian material samplers were placed in four tributary basins along the north shore of Lake Mead. Analyses of flood water quality samples were coupled with estimates of intermittent event volumes and the estimated volume of salt leaving BLM land was derived.

Calculated average TDS values for flows ranged from 1,270 to 2,000 mg/l. Water was generally a calcium sulfate type. TDS generally increased down-channel during an event. Estimates of peak discharges and volumes showed that the largest events occurred in the two largest drainage basins. Correlations of precipitation, geology and soils information with the quality and quantity of flood events were not evident from available data. Analyses of precipitation data did show that the study period coincided with a wetter than average period.

Results of analyses based on a series of conservative assumptions showed that 3,000 and 1,300 tons (2,700 and 1,200 metric tons) of salt entered Lake Mead from the study area in 1978 and 1979, respectively. This influx of salt would have increased the river's total dissolved solids (TDS) at Hoover Dam by 0.08 mg/l in 1978 and 0.04 mg/l in 1979. Extrapolation of generalized study results to include similar drainage basins associated with both Lake Mead and Lake Mohave showed that a total annual increase in TDS of 0.50 mg/l could be attributed to ephemeral basin runoff. Data on rates of accumulation of wind blown material collected in conjunction with water quality data were evaluated. Analyses of

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results showed 25,670 tons (23,100 metric tons) of soluble material could have been contributed to the reservoir annually. This would result in an increase of 0.72 mg/l in TDS at Hoover Dam. Data extrapolated over the areas of both Lake Mead and Lake Mohave showed a total annual increase in TDS contributed by wind blown material of 0.76 mg/l at Davis Dam.

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RESULTS AND CONCLUSIONS

1. The calculated average TDS values of intermittent flow water ranged from 1,270 to 2,000 mg/l.

2. Water quality of events was generally a calcium sulfate type. This is most likely a result of flood water dissolution of gypsum in basin soils.

3. TDS vs. distance analyses within individual basins showed that the TDS of intermittent events generally increased down-channel during an event. TDS vs. depth analyses at sampling points showed a general decrease in TDS at the 24 inch (30 cm) bottle position. For depths exceeding 24 inch (30 cm) TDS - depth relationships varied.

4. Estimates of peak discharges showed the largest events occurred in the Valley of Fire basin and Echo Wash basin. It is believed that the large basin areas and the distribution of rainfall accounted for these peak events.

5. TDS values coupled with the annual approximated volume of water leaving the BLM portion of the basin resulted in approximately 3,000 and 1,300 tons (2,700 and 1,200 metric tons) of salt entering Lake Mead from the study area in 1978 and 1979, respectively. Assuming total mixing in the maximum volume of Lake Mead, Colorado River quality at Hoover Dam may have increased by 0.08 mg/l in 1978 and 0.04 mg/l in 1979 as a result of intermittent flow salt loading.

6. The period of study coincided with a period of above-average annual precipitation, which has been equalled or exceeded four other times within 42 years of record.

Analyses of precipitation records for stations within the study area generally correlate with the Las Vegas record for this period. Though no data were available for the number, quantity and quality of flow events for a period of lower annual precipitation, it is assumed that annually the total runoff and salt loading per study area will be less than observed.

7. When records for the nine precipitation stations were analyzed in conjunction with peak flow data and rainfall intensity data recorded at Las Vegas, no discernible predictable relationships were evident.

8. The only generalization evident from the data relating basin topography and physiography to recorded events is that the largest two of the four basins had more frequent events and larger peak discharges.

9. Insufficient data was available to relate the soils and geology to the event characteristics.

10. Eolian material collected in the study area contained readily soluble salts. However, in the majority of study sites event water chemistry was not dominated by the eolian material. The calcium sulfate water common to the majority of flood events was most likely a function of bank and channel erosion and incorporation of weathered material containing those minerals. The presence of the sodium and bicarbonate sulfate dominated eolian material undoubtedly contributed in a minor degree to the overall water quality.

11. Calculations based on the average annual rate of accumulation of soluble eolian material within the study area

indicated that 25,670 tons (23,100 metric tons) of soluble salts may be added to Lake Mead annually. When this quantity is compared with the maximum reservoir storage capacity and complete mixing is assumed, an increase of 0.72 mg/l of TDS could be expected in lake water quality at Hoover Dam.

12. Results of an extrapolation of salinity loading rates from intermittent events and rates of eolian material accumulation to the area immediately tributary to Lake Mead and Lake Mohave, excluding the Moapa and Virgin River drainages, showed an approximate increase in TDS of 0.5 mg/l and 0.76 mg/l, respectively at Davis Dam.

13. Due to the reconnaissance nature of the study many generalizing assumptions were necessary to extrapolate water quality and quantity data. Additional research is needed to better define and predict flood discharge peaks and volumes, and related salt loading from intermittent flow events in arid environments.

INTRODUCTION

The Bureau of Land Management (BLM) has been mandated to provide quantitative and qualitative information on salt pickup and transport mechanisms that occur on public land and to assess measures which could result in improvement of the water quality of the Colorado River. The average annual salt load as measured at Hoover Dam is 10,336,000 tons (9,300,000 metric tons). Approximately 52 percent of the salt load is contributed by natural diffuse sources (USDI, 1978). The BLM-managed public lands contribute to that percentage. In the Upper Basin of the Colorado River it is recognized that range lands covered with perennial vegetation receiving greater than 12 inches (30 centimeters) of average annual precipitation contribute the greatest quantity of salt. A second significant source of salt load is from lands containing saline geologic and soil formations which receive less than 8 in. (20 cm) of annual precipitation (USDI, 1978).

It was in recognition of the need to identify the mechanisms and significance of salinity loading from arid ephemeral drainages in the Lower Colorado Basin that the BLM sponsored this reconnaissance effort. The project proposed to study the quality and quantity of intermittent flow events originating on lands administered by the Bureau of Land Management that are tributary to the Colorado River in southern Nevada. Work was begun in November 1977. Principal project objectives were to sample the water quality of flash flood events over a two year period in selected drainage basins and relate field data to the probable type and magnitude of salinity load arid basins could contribute to the Lower Colorado River Basin. An area along the north shore of Lake Mead considered characteristic of the Colorado watershed in the region was selected for study (Figure 1).

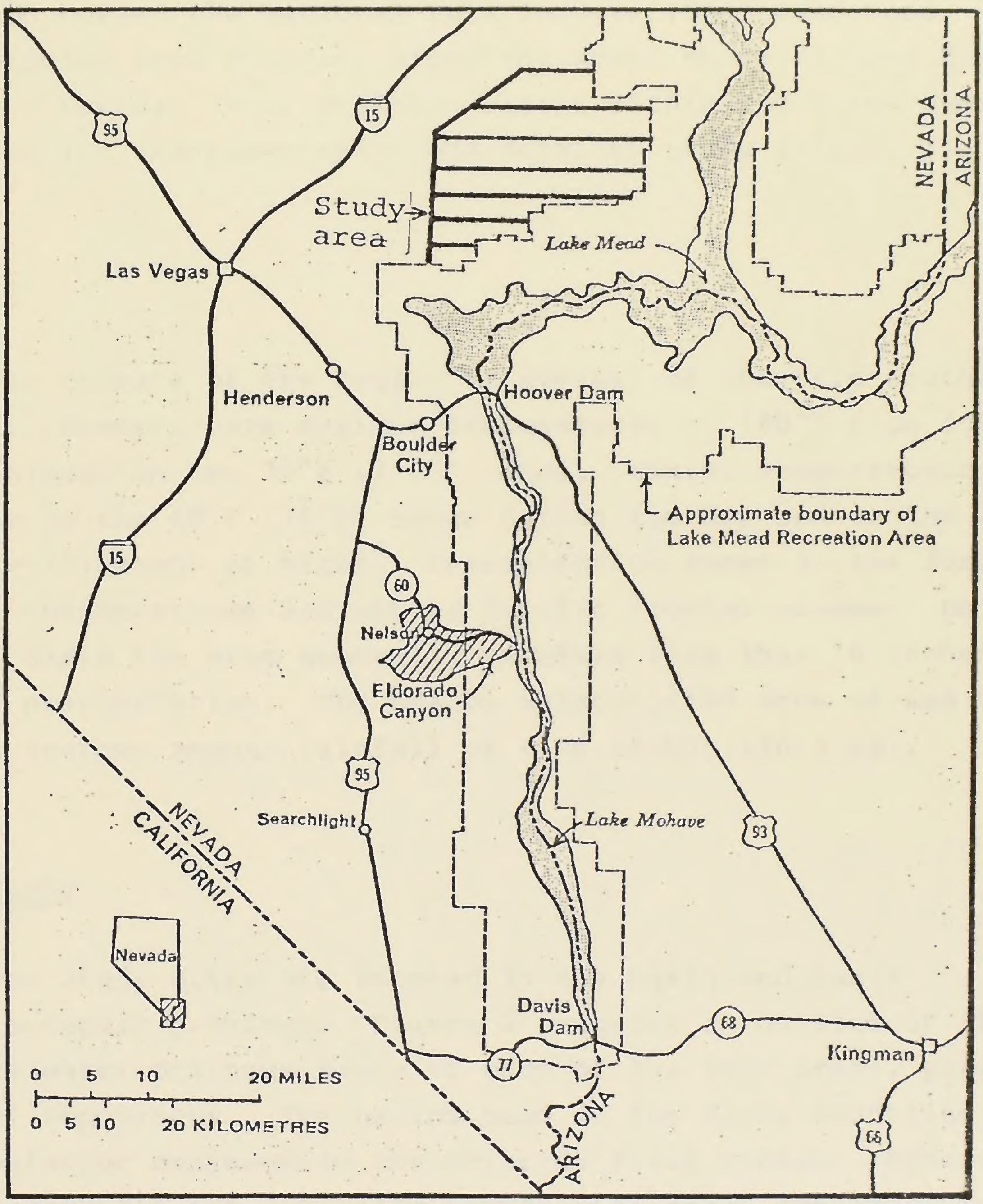

Figure 1: Location of study area (after Glancy and Harmsen, 1975).

[illegible]

General Site Description

The study area encompasses over 150 mi^2 (380 km^2) of BLM land borded the National Park Service (NPS) Lake Mead Recreational Area boundary along the north shore of Lake Mead in southern Nevada. Four drainage basins within the study area were selected for instrumentation and detailed study (Figure 2).

Climate

The climate of the region is typical of the arid southwest desert. Summers have maximum temperatures of 100°F plus (38°C) and minimums in the 70°F (21°C) range. Winter temperatures average in the 60°F (16°C) range during the day and in the upper 30°F (-1°C) range at night. Precipitation comes in the form of summer thunderstorms and winter Pacific frontal storms. On an annual basis the area generally receives less than 10 inches (25.4 cm) of precipitation. The nearby metropolitan area of Las Vegas has an average annual rainfall of 4.06 inches (10.3 cm).

Topography

The study sites are located in the Basin and Range physiographic province. Figure 2 presents an outline of the surface water drainage basin of each of the four areas, plus the general topography. The basins head in the Muddy Mountains and have exterior drainage to the Colorado River system. Ephemeral stream channels are generally narrow with steep gradients in the mountainous areas that widen and flatten in the basin interiors.

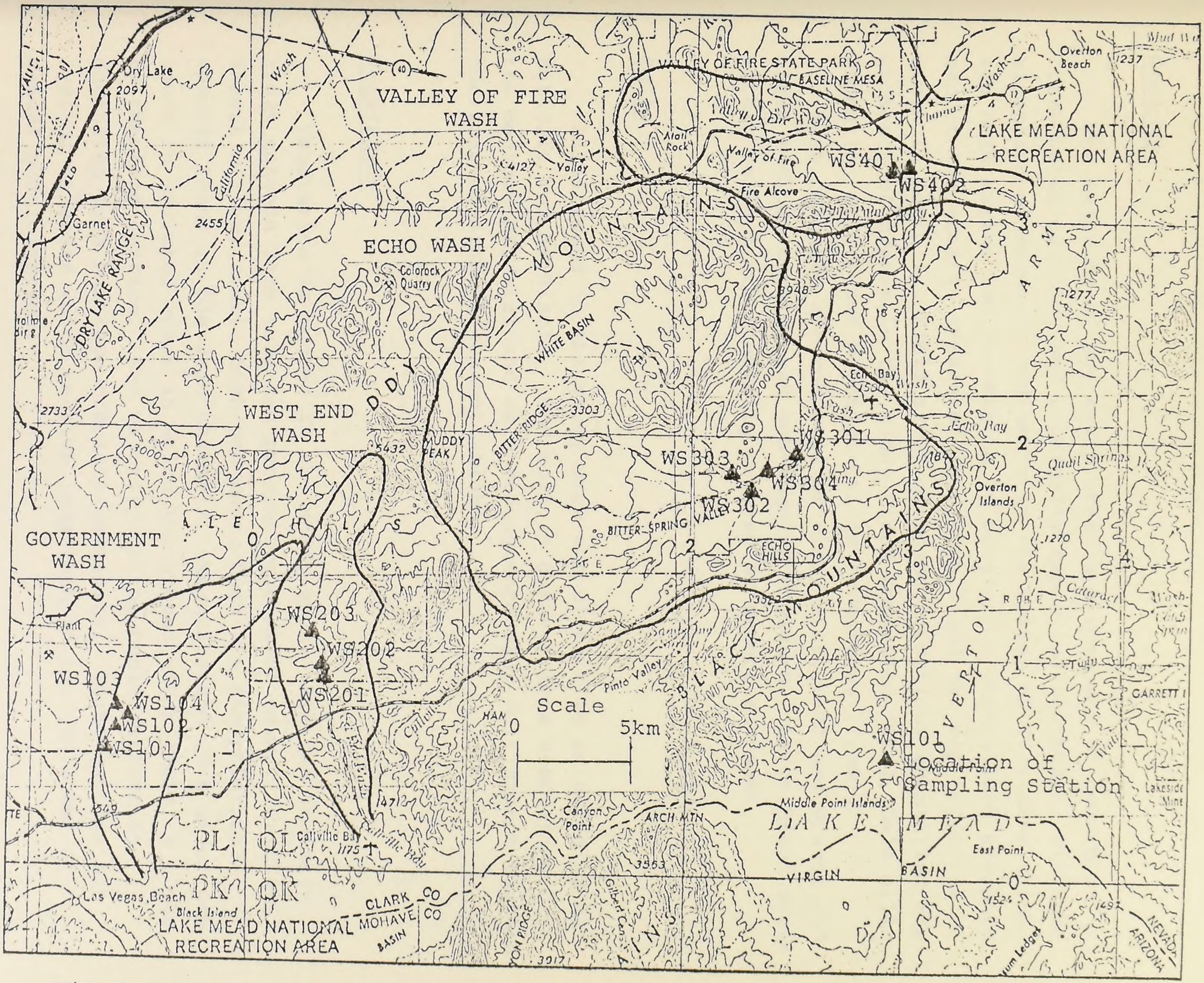

Figure 2: Location of study basins and water quality sampling stations.

Geology

The majority of the basin areas are composed of Cenozoic fresh water clastics and chemically deposited sediments, with the exception of Mesozoic sediments in the Valley of Fire area which are both marine and non-marine in origin. A generalized geologic map of the area is presented in Figure 3 and the map legend is given in Table 1. Field study of these formations identified the presence of gypsum in the Muddy Creek Formation (Tmc), Gale Hills Formation (TKg), and Moenkopi-Chinle Formations (Trcm).

Wash channels are composed of clay, silt, sand and gravel and often include angular and sub-angular boulders. Large broad areas within valleys are generally covered by desert pavement.

Soils

Soils found in the study area are classified principally as Entisols and Aridisols. The soil is derived from weathering of the bedrock material and as a consequence many soil groups contain horizons of mineral concentrations.

Vegetation

Vegetation is sparse in the study area. All the drainage areas contain less than ten percent vegetative cover. Catclaw, desert willow, rabbit bush and burro bush are the principal species found in the wash channels. Mesquite and salt cedar are found in isolated areas in which the ground water table is close to the land surface. The majority of the basin surface is dominated by a bur-sage-creosote community. These species are typical of areas which receive less than 10 in. (25.4 cm) of annual precipitation.

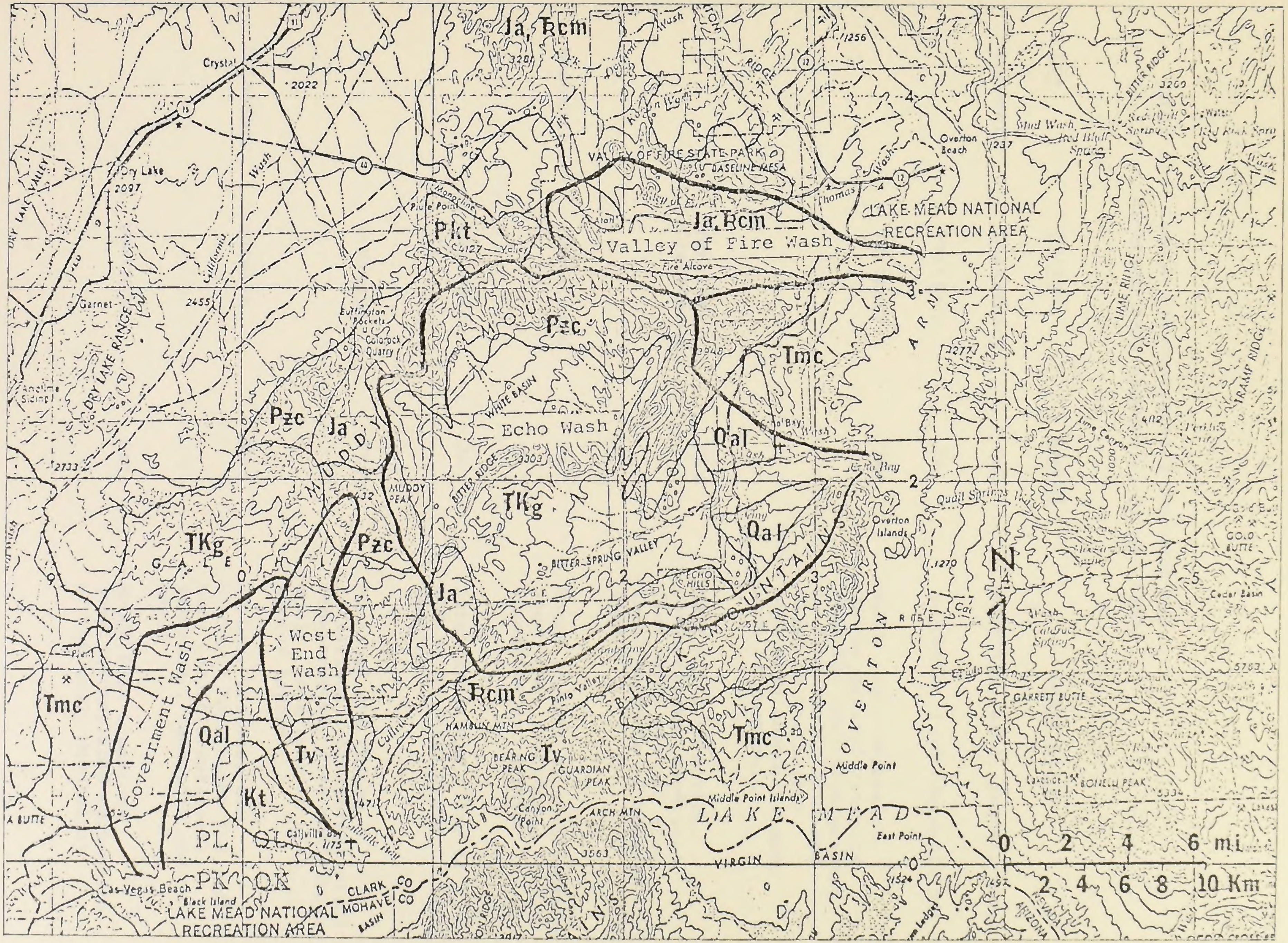

Figure 3: Generalized geology of the study area (after Longwell et al., 1965).

Table 1: Legend for Generalized Geologic Map of Study Area (Longwell, et al, 1965)

Era	System	Symbol	Description
Cenozoic	Quaternary	Qal	alluvium, sand, gravel, clays
	Tertiary	Tv	volcanics (undifferentiated)
	Tertiary	Tmc	Muddy Creek Formation, coarse grained clastics near the mountains grading to fine sands, nets and clays in the basins, gypsum is abundant, some beds of rock salt
	Tertiary? Cretaceous	TKg	Gale Hills Formation, conglomerate, sandstone, fine sand, net and clay, local deposits of boulder rubble
Mesozoic	Cretaceous	Kt	Thumb Formation, conglomerate, sandstone, siltstone, limestone and gypsum
	Jurassic	Ja	Aztec sandstone, fine to medium grained, cross bedding
	Triassic	Trcm	Moenkopi and Chinle Formations (undifferentiated) conglomerate, fine sandstone, shale, interspersed with gypsum layers
Paleozoic	Permian	Pkt	Kaibab, Toroweap and Coconino Formations and red beds (undifferentiated), limestone, sandstone and shale
	Devonian	Pzc	Muddy Peak limestone (undifferentiated carbonates of the Muddy Mountains)

Intermittent Flow Events

An intermittent flow event or flash flood-debris flow in an arid environment is a unique hydrologic event. It is generally initiated as a result of an intense precipitation event within a basin. Runoff from steep, low permeable surfaces in basin lands can combine with sheet flow from the more gentle basin floor to create stream flooding in the shallow basin channel. The flash flood involves water and debris moving at high velocities. The durations of events are short with most lasting only a few hours.

The quality, frequency and magnitude of intermittent events are difficult to predict because of the absence of detailed data networks needed to provide information on the distribution and intensity of precipitation events and resulting flood characteristics. Many factors influence the quantity and quality of intermittent events:

1. Precipitation intensity and distribution
2. Physical basin characteristics; i.e., area, shape, slope channel lengths and widths
3. Basin geology and soils; i.e., distribution, erodeability, and chemistry
4. Basin vegetation; i.e., type, percent of ground cover, distribution

Each of these factors have an influence on the resulting character of an individual event. However, the relationships are complex and rarely are there sufficient data bases to clearly correlate information and accurately predict flow quantity and quality in an arid environment. As a result, the current study was designed to measure the quality of intermittent events and derive peak flows and volume of events in order to relate runoff to receiving water quality. Available data on precipitation, basin physiography, geology, soils and vegetation were collected to determine the degree to which study results could be extrapolated.

PREVIOUS STUDIES

The BLM published quality and discharge records for one intermittent event observed in Utah and reported on data for two other events for which the United States Geological Survey (USGS) had limited data in their discussion of salinity loading from ephemeral drainages in the Upper Colorado River Basin (USDI, 1978). Prior to the current study and the Upper Colorado River study little attention had been given to examining the water quality of flash flood events. The principal concern of previous investigators has been prediction of peak flows for engineering design purposes and protection of life and property. Work in the Lower Colorado River Basin by the USGS has centered on documentation of a severe flood event at Eldorado Canyon, Nevada and prediction of possible flood peaks at Willow Beach, Arizona (Glancy and Harmsen, 1975; Mooseburner and Glancy, 1978). Researchers at the Department of Agriculture Southwest Rangeland Watershed Research Center (SRWRC) in Tucson, Arizona have conducted numerous research efforts on highly instrumented semi-arid ephemeral watersheds near Tucson. However, the absence of parrallel data in the arid southern Nevada region hampers identification of the transferability of methods and results. Based on review of numerous (SRWRC) articles and their 1978 publication list no work had been directed toward intermittent water quality assessment of undeveloped watersheds. The USGS developed a relationship of peak flow to total event volume for the Arizona Department of Highways which was applicable to this study (Aldridge, 1980, personal communication). Numerous methods to predict flow peaks and volumes based on geology, soils, basin geomorphology, vegetative cover and land use have been developed over the years. However, the absence of detailed data on precipitation distribution intensity, and basin discharge precluded their use in this reconnaissance study.

METHODOLOGY

The area selected for study centered around ephemeral drainage basins along the north shore of Lake Mead. Four drainage basins, Government Wash, West End Wash, Echo Wash and Valley of Fire Wash (Figure 2) were selected for study based on the following criteria:

1. Flash floods had been observed in each drainage area;
2. Each basin contained a large percentage of BLM land that drains directly into the Colorado River;
3. Basins had as much variation as practical in criteria such as topography, size, geology, soil type and vegetation, which influence flash flood volume and water quality, and
4. A paved road provided easy access to the sites.

Remote runoff sampling devices were placed in each wash at the BLM-NPS boundary and upstream at major channel bifurcations (Figures 4A-4D). The sampling devices consisted of a steel fence post with 1000 ml bottles attached in a manner that the tops of the bottles were at 2, 12 and 24 inches (5, 30 and 60 cm) above the wash bed (Figure 5). The sampler sites are labeled with the prefix WS. From four to eight 0.13 inch (0.32 cm) holes were drilled in the bottle caps to permit filling with water as the bottles were overtopped by flood water. Bottles were collected as soon as practicable after each event. New bottles were secured to the post when water samples were collected.

Water was analyzed for pH, specific conductance (SpC), HCO_3^-, CO_3^{2-}, Cl^-, SO_4^{2-}, Na^+, K^+, Ca^{2+}, Mg^{2+} and Si^{2+}, using standard techniques. Comparison and contrasts of general water quality were done in terms of the concentration of total dissolved solids (TDS). These values were calculated multiplying the laboratory specific conductance (SpC) by a factor of 0.77. The factor was derived by comparing calculated TDS values and SpC values from laboratory analyses and taking an average of the

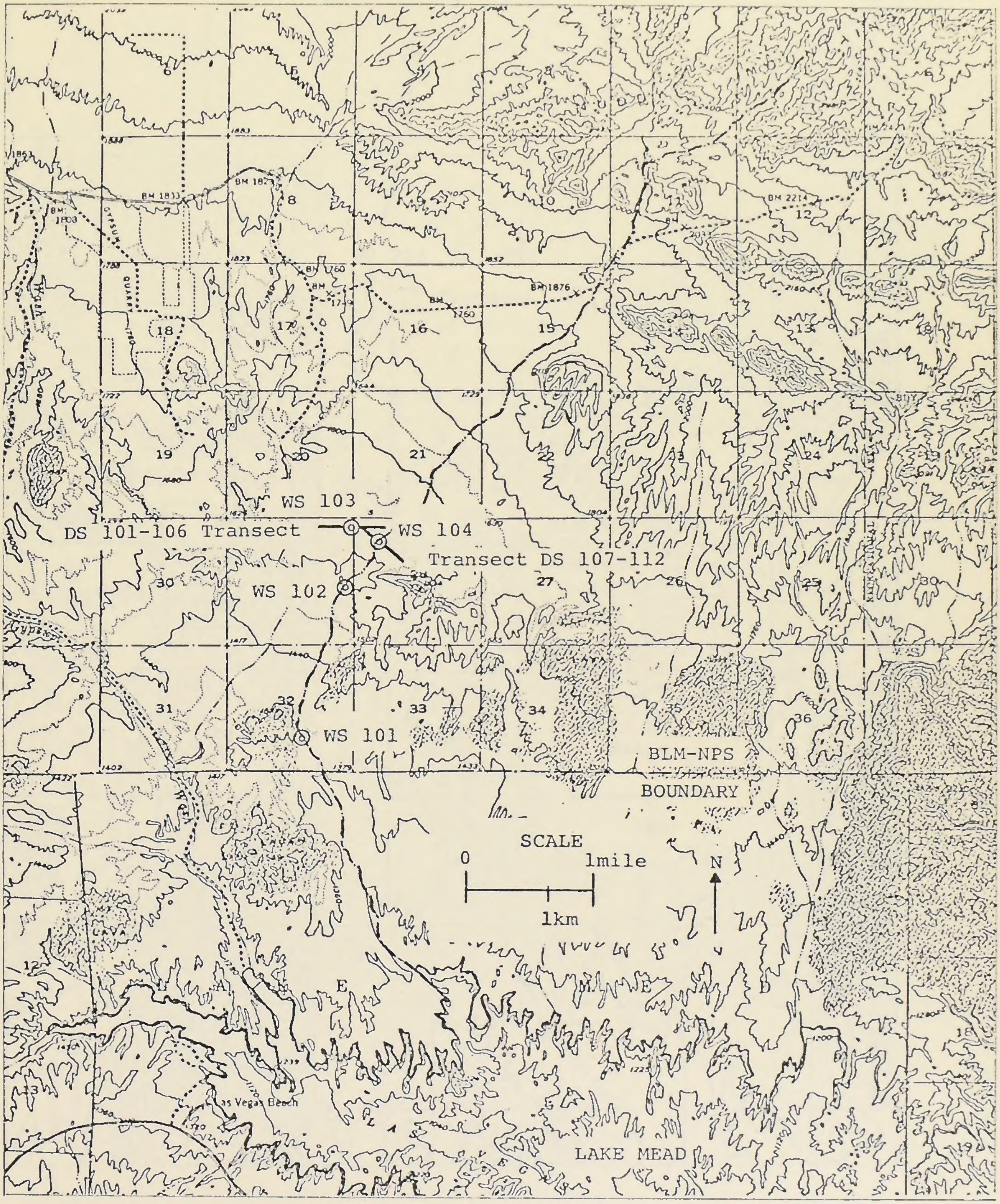

Figure 4A: Location of event water samplers (WS) and eolian material samplers (DS), Government Wash.

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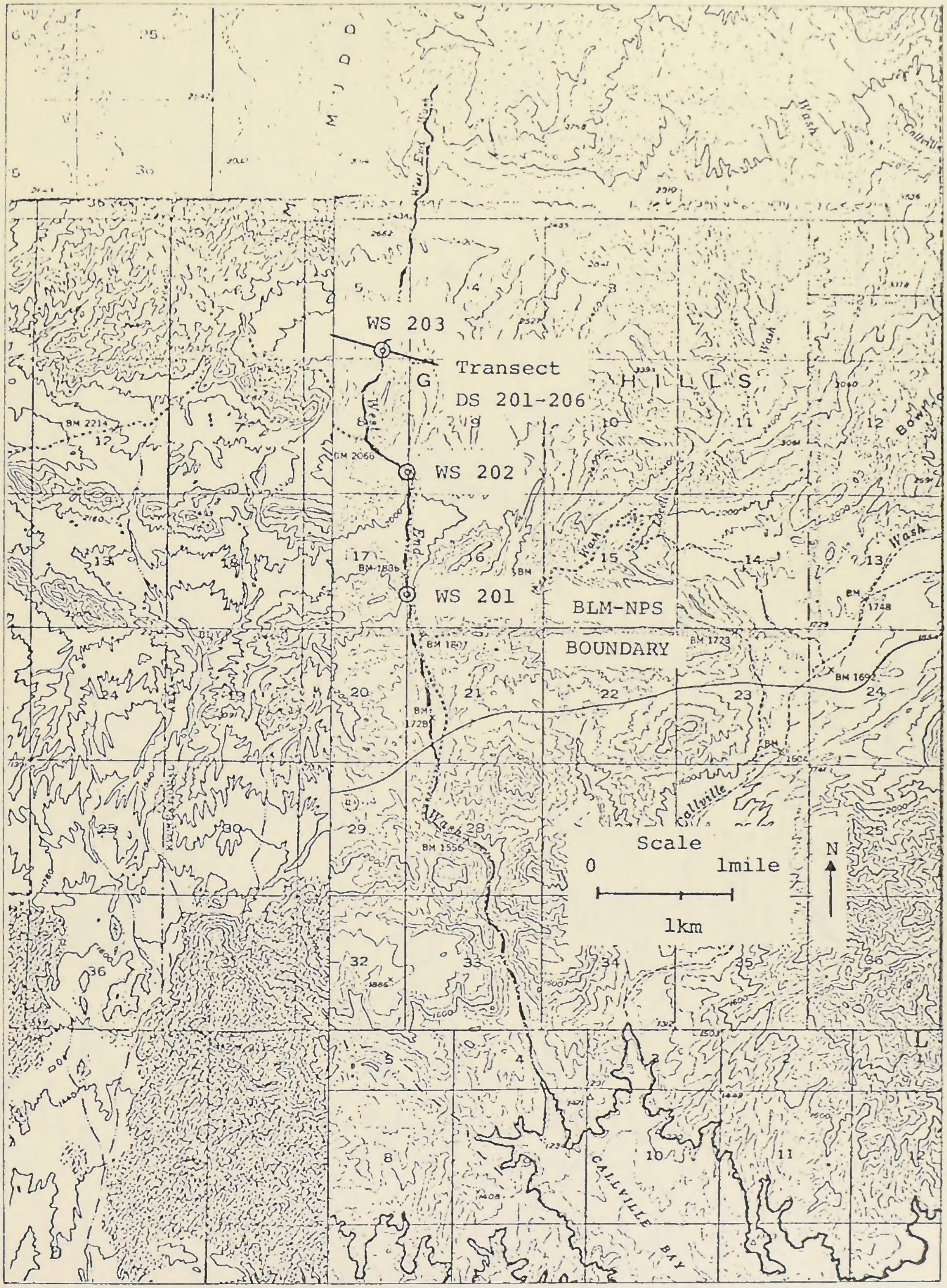

Figure 4B: Location of event water samplers (WS) and eolian material samplers (DS), West End Wash.

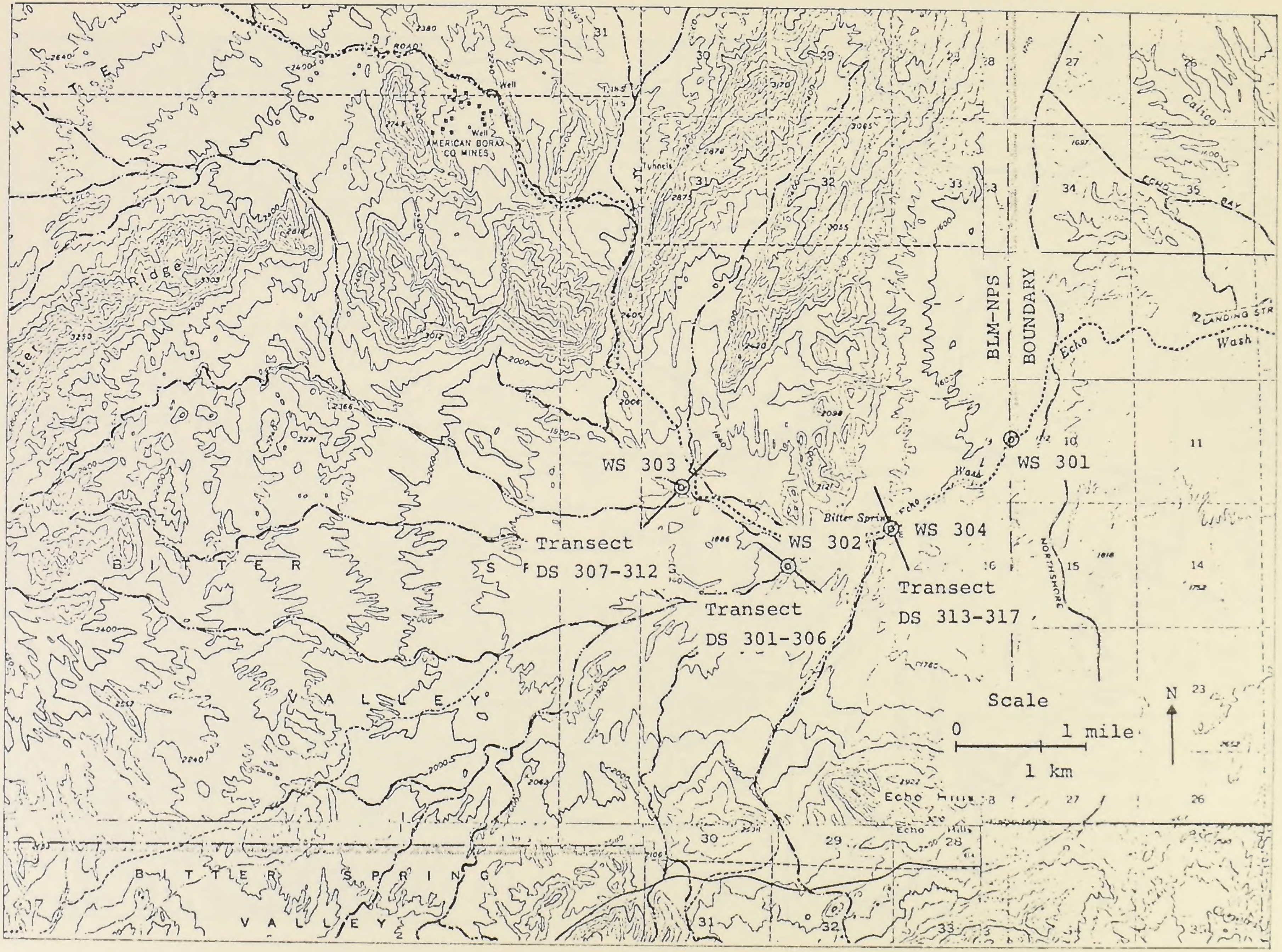

Figure 4C: Location of event water samplers (WS) and eolian material samplers (DS), Echo Wash.

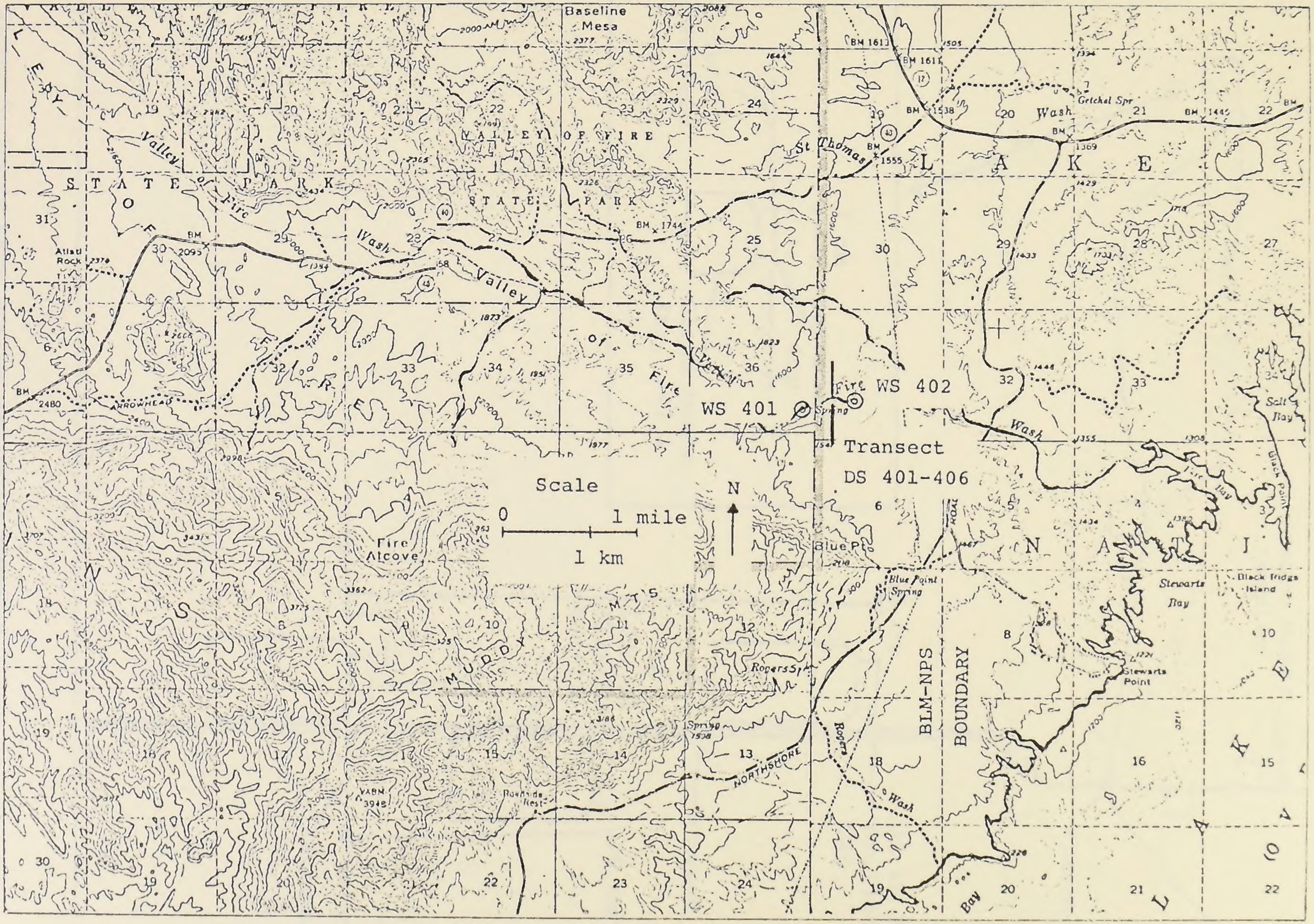

Figure 4D: Location of event water samplers (WS) and eolian material samplers (DS), Valley of Fire Wash.

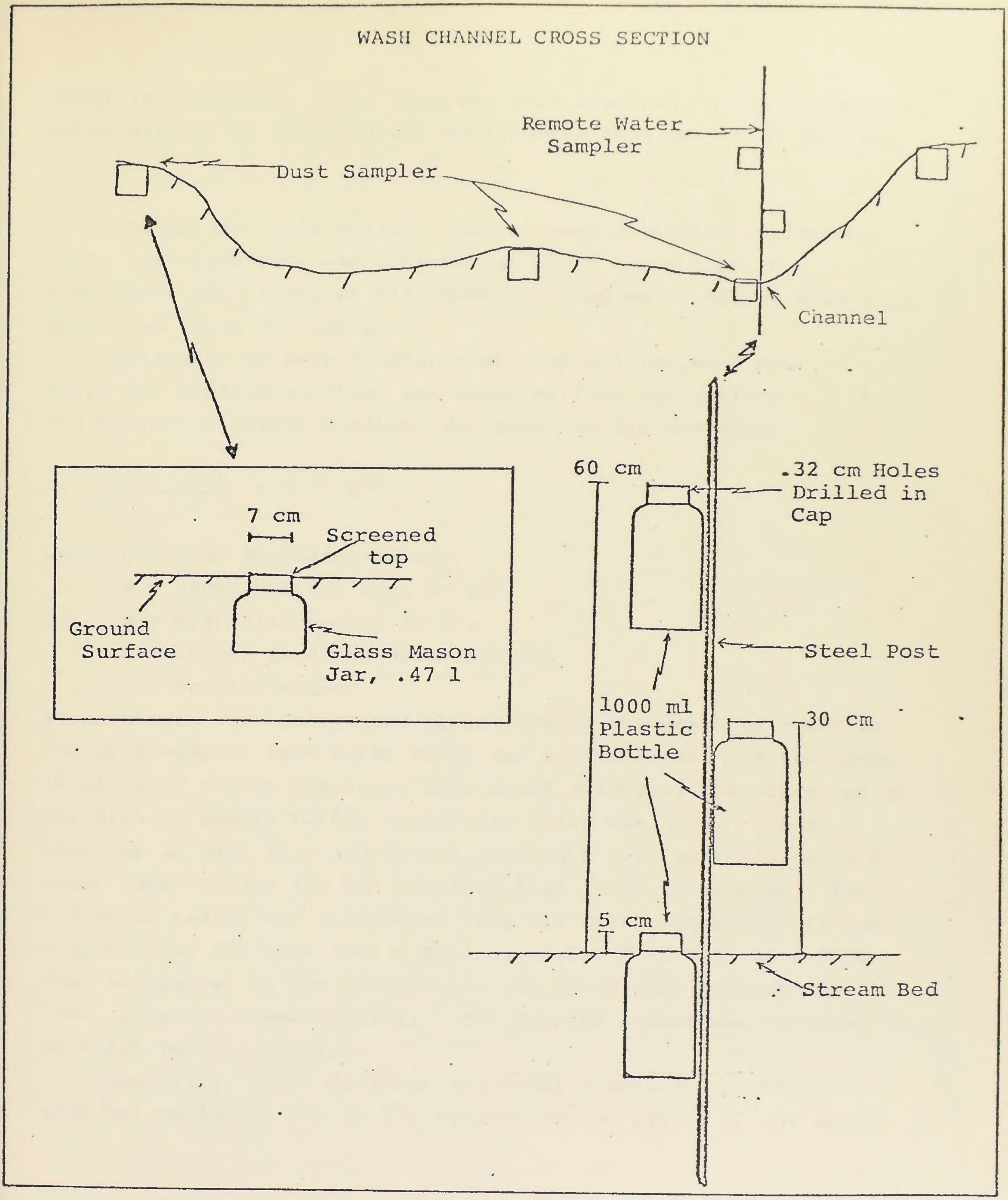

Figure 5: Remote water sampler and eolian material sampler (dust sampler) design.

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[illegible]

resulting factors. Stiff diagrams were prepared to aid typing the water quality by plotting the milliequivalents per liter for the

Additional water quality samples were collected during one event for which flow was observed at North Shore road in Government and Valley of Fire Washes. Samples of spring discharge were also taken for analyses.

Estimates of peak discharge at each station were made by using the Manning equation and assuming flow was uniform and that the hydraulic energy gradient was equal to the bed slope:

$$Q = \frac{1.486}{n} A R^{.67} S^{.5}$$

where Q = peak discharge in cfs,
A = cross section area in ft^2,
R = hydraulic radius in ft,
S = energy gradient dimensionless
n = Manning number

Water stages were determined by estimating the depth of water at the pole sampler from water marks and debris lines. If the water level could not be discerned from other evidence, the elevation of the highest sample bottle containing water was used. Cross sections at each site and stream gradients were surveyed using a steel tape, stadia rod and standard hand level techniques. The hydraulic radius was calculated from the cross sections. It was suggested by the USGS that a Manning number from 0.02 to 0.03 be used as typical of the channels in the study area (Mooseburner, 1980, personal communication). The Manning number was selected to be 0.025 for all sections.

Generally, event duration and total discharge information were not collected due to the reconnaissance nature of the study.

However, on an experimental basis, two gaging stations containing event starting clocks were designed and installed in Echo Wash in June, 1979 in an attempt to measure duration and volume, (Figure 6). One event was recorded, however, only one station recorded flood stage and duration.

In an effort to estimate the volume of water associated with each peak event the following relationship developed by the USGS for the Arizona Department of Highways was developed:

$$V = 0.0008\ P^{1.5}$$

where V = volume in acre feet

P = peak discharge in ft^3/sec

This relationship was developed by comparing measured volumes and discharges from gaged watersheds in northern Arizona (Aldridge, 1980, personal communication). The annual total discharge of events which occurred at the BLM-NPS boundary within each basin was then coupled with calculated TDS values at those stations and the quantities of salt derived from the basins within the study period were calculated. It was assumed that the flood waters containing calculated quantities of salt reached the Colorado River system either by directly flowing into Lake Mead or by moving to the lake as interflow or groundwater flow. It should be realized that this is a simplification of the actual transport mechanisms and that a portion of the salinity and some flow from each event may be retained in the unsaturated zone or used by phreatophytes.

The distribution of precipitation and the topography, geology, soil types and eolian material in each basin were evaluated in an attempt to account for the variations in quality and quantity of flow events. Precipitation records for the Las Vegas area were obtained from the National Oceanic and Atmospheric Administration (NOAA). Records from daily observations at ranger stations in the Lake Mead National Recreational area for the period of 1975 to 1979 were also analyzed. Figures 7A and 7B show the location of stations with respect to the study area. Basin

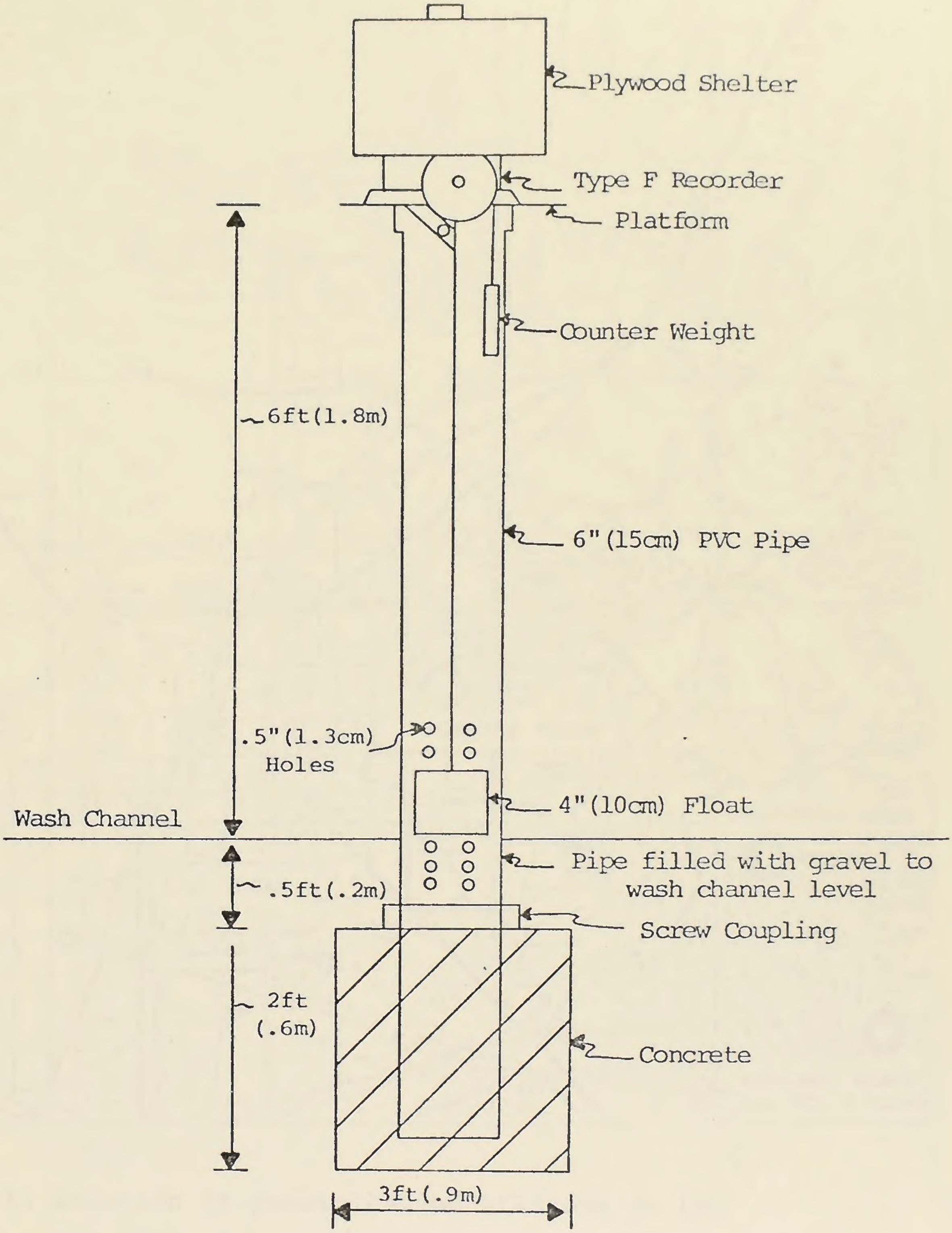

Figure 6: Gaging house design.

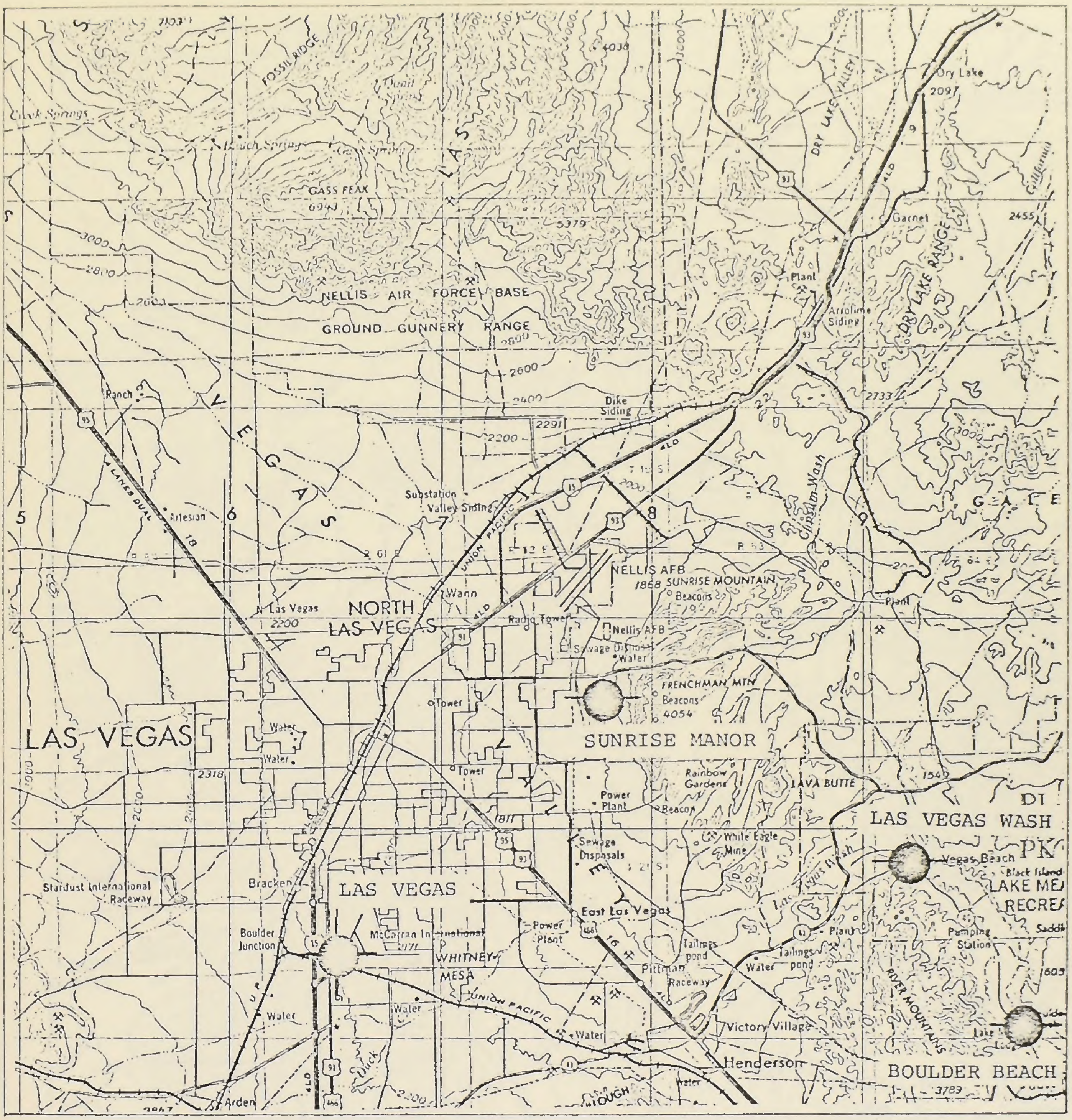

Figure 7A: Location of precipitation stations in the vicinity of the study area, West area.

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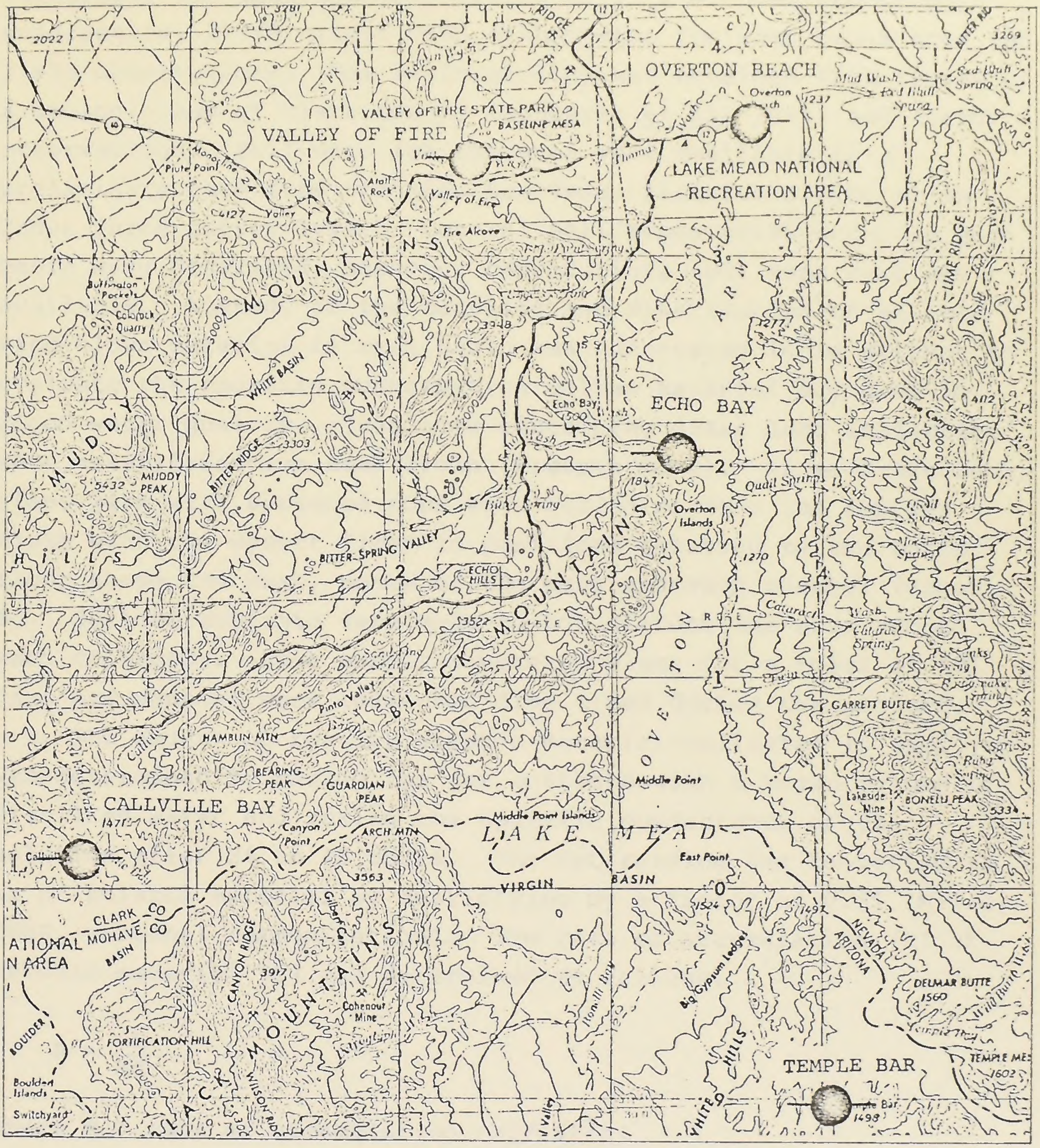


Figure 7B: Location of precipitation stations in the vicinity of the study area, East area.

[illegible]

topography was obtained from review of 15 min. USGS topographic quadrangles, 7 1/2 minute USGS orthophotos for each basin area and field observations. The basin geology was obtained from review of a geologic map of Clark County (Longwell et al, 1961) and field observations. Soil data for the area were available in a preliminary form from the BLM, Las Vegas district office at an Order Three survey level. General soil types which occur in each basin were described, however, reproducible soil maps were not available. A study of the quantity and distribution of soluble wind-blown material in each basin was undertaken in an attempt to evaluate the possible contribution eolian material may have on flood water quality. Transects containing glass dust collectors were established for each basin (Figures 4A-D). At each transect, glass jars with screened tops were buried so that the top was flush with the desert floor in positions relating to the basin floor above the wash, banks of the wash and wash channel (Figure 5). Serious attempts were made to not disturb the area around each collector. Dust samplers were in place for a total of 573 days and samples were collected five times during the project.

The amount of readily soluble material collected in each jar was determined by mixing the jar contents with a known volume of distilled water and taking the specific conductance of the solution after 24 to 48 hours. The SpC reading was converted to mg of soluble material by multiplying by a factor of 0.55 (Miles, 1980, personal communication). The rate of accumulation (R) of soluble material (C) was determined as follows:

$$R = \frac{C}{Ad}$$

where R = rate of accumulation, mg/(ft^2d)

C = concentration of soluble material, mg

A = area of the opening of the collection jar, .028/ft^2

d = number of days jar was emplaced in the field.

The drainage basins were examined and information on the accumulation of eolian material was grouped depending on the location of the sampler: 1) broad basin floor between discrete channels, Zone I; 2) slopes of the washes, Zone II; 3) the wash channel, Zone III (Figure 8). The rates of accumulation within each zone were averaged for each of the collection intervals, excluding the fourth period where samples were analyzed for gross chemistry. The remaining four average rates were averaged to calculate a rate of accumulation considered representative of the daily rate for a specific zone in a specified watershed.

Individual samples derived from the fourth period of dust collection were composited based on classification by zone of accumulation (Figure 8) for each wash basin. Samples were weighed and then combined with a measured volume of distilled water. After 24 to 48 hours the sample was filtered and the filtrate was analyzed for sulfate, chloride, calcium, magnesium, sodium, potassium, alkalinity and milligrams of soluble material per sample. Laboratory results were converted to milligrams of soluble material per kilogram of eolian material. The dominate chemical constituents in the solute were identified after Stiff diagrams were prepared.

STUDY RESULTS

The results of this intermittent flow study are presented with the emphasis on water quality, principally TDS, of recorded events. The first section on water quality of flash flood events presents the results of gross chemical analyses, water types, and variations of water chemistry with flow depth within each basin, and compares and contrasts the chemistry of each basin. The second section on calculation of peak discharge and flow volumes describes results of attempts to quantify events. The third sec-

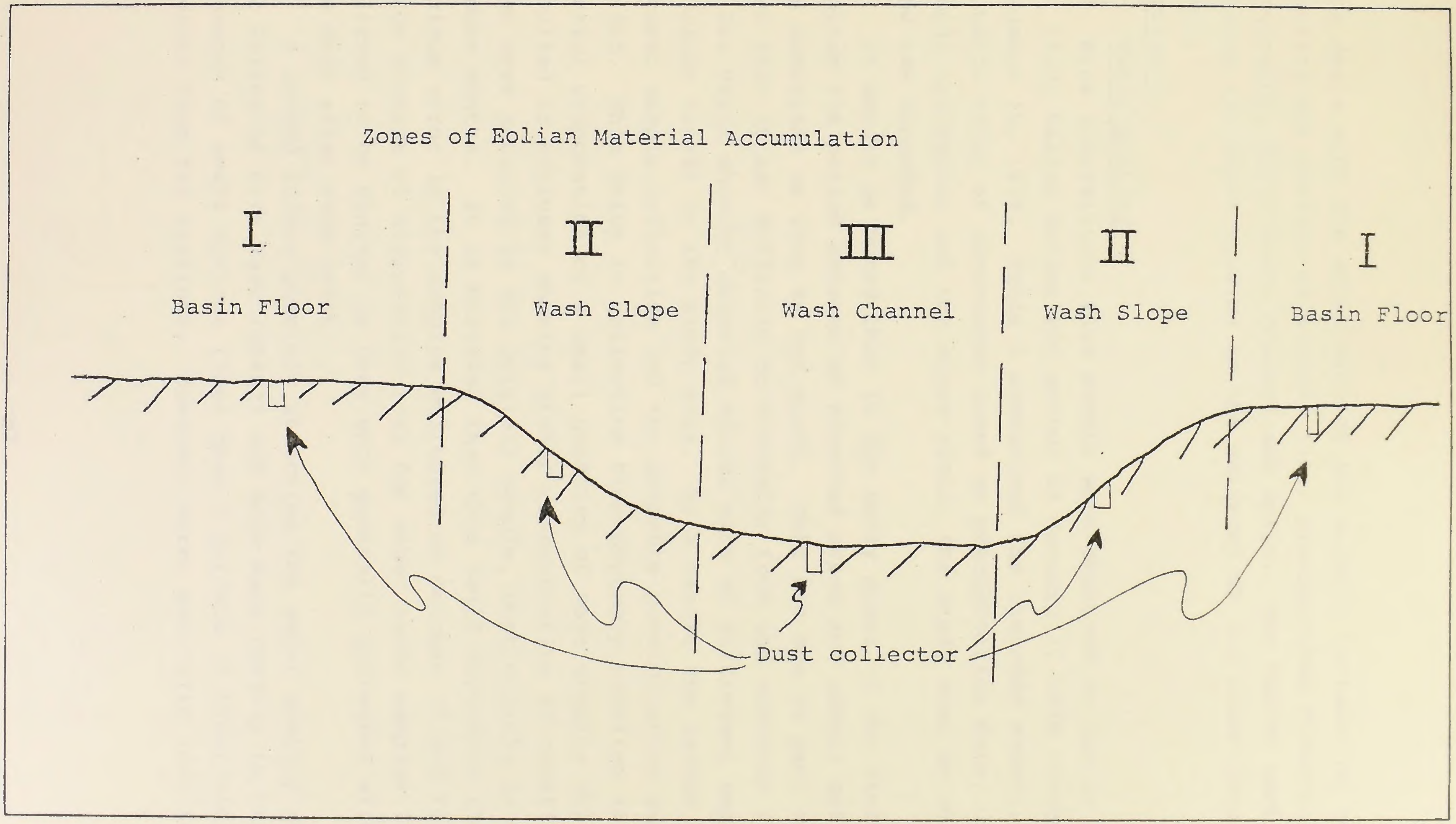
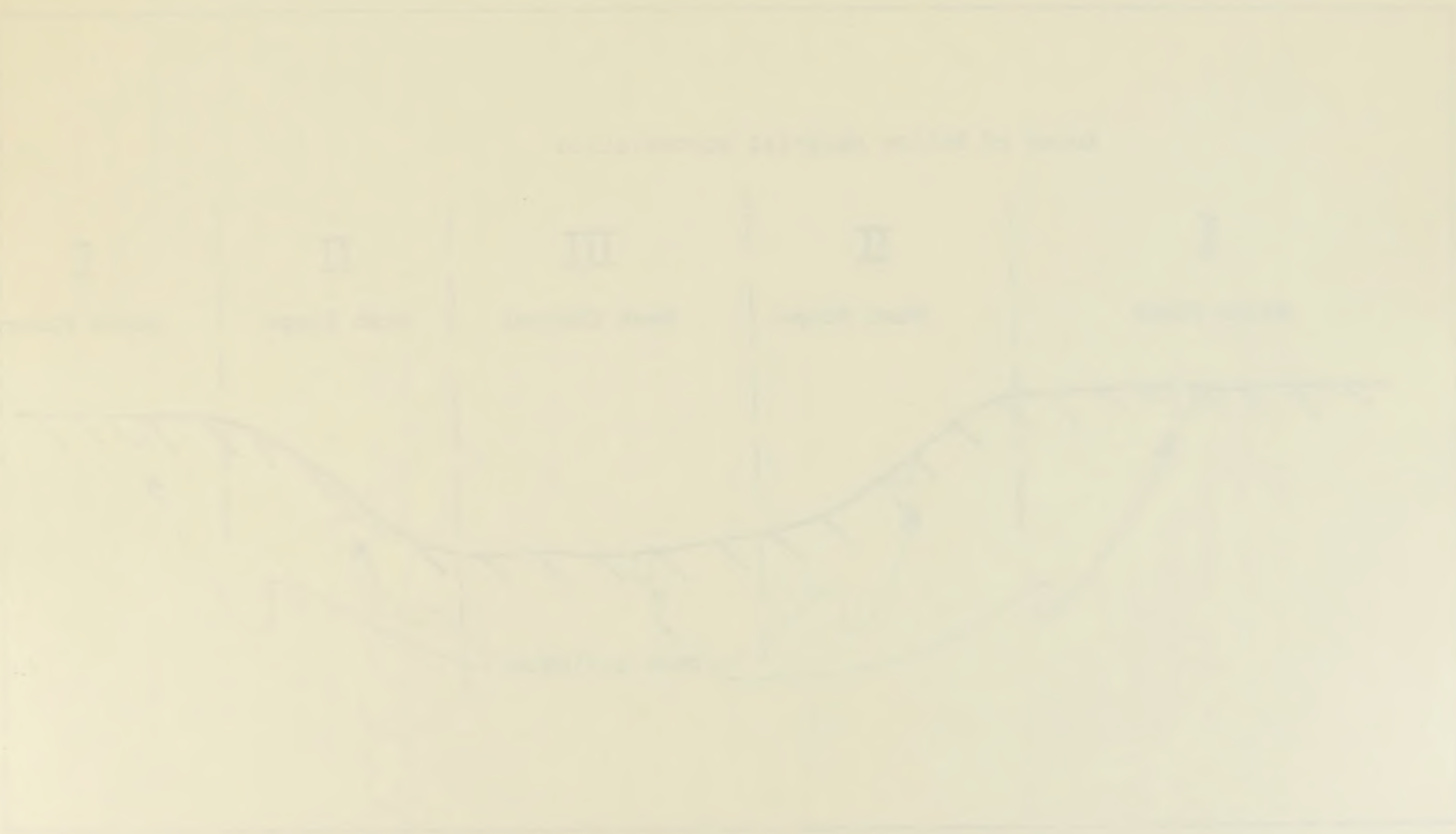


Figure 8: Zones of accumulation of eolian material.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tion deals with the assessment of the factors influencing the quantity and quality of events; i.e., precipittion distribution, topography, basin size, geology and soils. The fourth section relates the basin studies to the salinity of the Lower Colorado River.

Section 1

Water Quality

Nine intermittent flow events were observed in one or more of the study basins during the period of January 1, 1978 through December 18, 1979. Table 2 summarized the recorded events, their probable dates of occurrence based on precipitation data, dates of sample collection and the sites within the study area at which flow was recorded.

It should be noted that in the early phase of the field program the period between an expected event and sample collection was sometimes as long as one month. This was due in part to the fact that it was difficult to determine from the research center in Las Vegas whether observed storms were of sufficient magnitude to cause runoff in the study area. As a result the length of time between sample collection and the probable precipitation event varied. This delay in collection time probably resulted in partial evaporation of a small quantity of some samples which resulted in analyses showing higher concentratins of constituents than were actually in the original sample, particularly in the summer months. It is believed that this would introduce the maximum error in the samples collected on October 17 and 18, 1978. Error because of evaporative loss for other later samples is believed to be minimal as they were generally collected within a few days after each event.

A second factor possibly affecting the water quality results for Valley of Fire Wash (WS402) and Echo Wash (WS301) is the presence of small springs (less than 1 gal/min (2 liter/min) up channel from the stations. However, water generally infiltrates

Table 2 : Summary of Intermittent Flow Events

YEAR	Probable dates of event	Dates of sample collection	Government Wash (WS#)*	West End Wash (WS#)	Echo Wash (WS#)	Valley of Fire Wash (WS#)
1978	2-9 and 2-10	2-10	BLM100**			BLM400**
	4-30 to 5-2	5-24	101, 102, 104	201 I		NI
	7-26 to 7-29	8-2				401, 402
	9-14 and 9-15	10-17 and 10-18	101, 102, 104		301, 302, 303, 304+	401, 402
	10-20 to 10-22	10-26			301, 302, 303, 304	
1979	3-27 to 3-29	3-29				401 I, 402 I
	5-25 to 5-27	6-14			303 I	
	8-12 to 8-14	8-15			301, 302, 303, 304	401+, 402+
	8-16 to 8-19	8-21	101, 102			401, 402 NI

* WS, water sample station
** runoff sample at North Shore road
I insufficient sample for analyses
NI not instrumented
+ sampling station destroyed by flow

or evaporates less than 1,000 ft (300 m) from the spring site and is considered to have a minimal effect on the overall water quality results.

Analyses of samples of the flood water are summarized for each basin in Table 3. Forty samples were collected and analyzed for gross chemical constituents. Calculated TDS values (Lab Spc x 0.77) ranged from a high of 2,600 mg/l at WS303 (60 cm bottle) on 10-17-78 to 540 mg/l at WS401 (5 cm bottle) on 8-21-79. The average TDS values at the four stations at the BLM-NPS boundary are listed below:

Basin	Station	# of samples	TDS mg/l
Government Wash	WS101	3	2,000
West End Wash	WS201	0	no data
Echo Wash	WS301	3	1,570
Valley of Fire Wash	WS402	2	1,270

The TDS of the highest bottle full for each event was used as it is believed that it would also relate to the water quality of the major volume of each flow.

Analyses of data presented in Table 3 indicated that the water quality varied with depth of flow at stations where more than one bottle was filled by the event. Figure 9 was developed in an attempt to determine whether trends could be noted. In a general sense it appears that at the 2 to 24 inch (5 to 30 cm) interval two-thirds of the samples showed a decline in TDS at the higher sampling point. At the 24 to 48 inch (30 to 60 cm) interval samples indicated the opposite trend. The difficulty in generalizing from the data is illustrated by samples WS303 (10-17-78) and WS304 (10-26-78). Both are in the same basin and TDS values are available at all three positions, yet analyses of data shows opposing trends.

TABLE 3: WATER QUALITY DATA

AREA	DATE of COLLECTION	SAMPLE NUMBER	SAMPLE POSITION (cm)	LAB SpC μmhos/cm	pH	IONIC CONSTITUENTS (mg/ℓ)							
						HCO_3	Cl	SO_4	Na	K	Ca	Mg	Si
GOVERNMENT WASH	2/10/78	BLM100	runoff*	1514	7.4	204	4	634	6		300	16	
	5/24/78	WS101	5	1413	7.3	255	8	813	10		315	26	
		WS102	5	1642	7.4	222	11	1059	20		367	27	
		WS104	5	2189	7.5	193	14	1560	22		540	21	
	10/18/78	WS101	5	2360	7.126	332	21.0	1008	13.0	9.6	640	38.5	12
		WS102	5	1680	7.332	218.4	11.0	920.3	11.0	6.4	346	33.2	10
		WS104	5	2243	7.244	148.0	13.0	1446.2	12.4	8.7	524	33.4	6
	8/21/79	WS101	5	4010	7.2	139	0.7	11.5	2.4	3.4	58	5.3	20
		WS102	5	696	7.0	84	4.3	208	5.0	10.5	102	5.1	10
WEST END WASH	5/24/78	WS201	5			Insufficient Volume for Analyses							
ECHO WASH	10/17/78	WS301	5	2437	7.423	151.2	38.0	1420	39.3	8.7	520	45.6	14
		WS302	5	2796	6.978	357.0	58.0	1578	26.4	7.6	782	37.5	19
		WS302	30	2078	7.093	210.0	25.0	1025.6	11.5	6.3	484	22.2	12
		WS303	5	798	7.192	265.0	11.0	159.9	9.2	4.7	138.0	21.8	5.0
		WS303	30	991	7.237	280.6	60.0	236.7	22.8	14.7	178	13.1	18
		WS303	60	3389	-	-	-	-	-	-	-	-	-
	10/26/78	WS301	5	2525	7.392	162	15.0	1504.1	36.8	7.5	626	44.5	5
		WS301	30	1825	7.172	176.4	16.0	947.3	18.6	6.4	464	18.4	10
		WS302	5	1251	7.493	133.4	3.6	594.2	2.5	2.1	268	9.4	9
		WS303	5	389	7.323	184.8	0.8	<10	0.3	1.9	62.0	4.8	3
		WS304	5	2408	7.599	136.5	5.0	1343	6.8	5.8	642	38.3	4
		WS304	30	2408	7.098	281.4	3.2	183	4.4	6.1	702	30.1	19
		WS304	60	1524	7.084	168.0	1.8	806	1.7	4.0	418	12.2	11

WATER QUALITY DATA

AREA	DATE of COLLECTION	SAMPLE NUMBER	SAMPLE POSITION (cm)	LAB SpC µmhos/cm	pH	IONIC CONSTITUENTS (mg/ℓ)							
						HCO_3	Cl	SO_4	Na	K	Ca	Mg	Si
ECHO WASH	8/15/79	WS301	5	2780	7.1	--	22.4	--	68.9	13	514	58.4	26
		WS301	30	1850	6.9	140	16.4	667.9	18.1	10.2	359	21.4	21
		WS302	5	1500	7.1	417	33	27.6	14.7	10.8	332	27.9	26
		WS302	30	1590	6.9	153	4.6	541	16	8	308	20.2	16
		WS303	5	825	6.8	296	4.9	30.0	7.7	6.2	130	9.2	15
		WS303	30	668	6.9	134	2.5	187	6.0	5.2	112	7.1	17
		WS304	5	2750	6.7	511	6.85	1339	8.8	12.4	500	24.4	32
		WS304	30	3130	6.9	334	18.3	1398	8.2	13.7	548	38.4	60
	3/23/78	Bitter Spring		4076	7.2	254	123	2303	256	14.6	518	155	15
VALLEY OF FIRE WASH	2/10/78	BLM400	runoff	858	7.6	114	13	307	13		145	8	
	8/02/78	WS401	5	2043	7.4	1104	19	116	16		322	37	
		WS401	30	1398	7.2	363	28	472	22		250	24	
		WS402	5	3279	7.3	810	90	1416	120		595	425	
		WS402	30	2365	7.0	390	51	1072	56		88	53	
	10/17/78	WS401	30	918.0	7.062	273	--	--	14.3	13.1	246	48.6	10
		WS401	60	791.0	7.532	336	15.0	--	12.4	8.7	208	21.0	8
		WS402	30	857.0	7.594	330	16.0	170.9	14.1	11.0	266	30.4	9
		WS402	60	934.0	7.265	369.8	14.0	158.0	12.9	8.6	190	22.6	10
	8/21/79	WS401	5	850	6.7	235	22.3	76.2	13.2	7.0	142	12	16
	5/24/78	Valley of Fire Spring		3781	7.6	222	185	2378	290	40.5	480	206	20

*Runoff = grab sample from flowing water, numbers are depths in centimeters of collection device above channel bottom

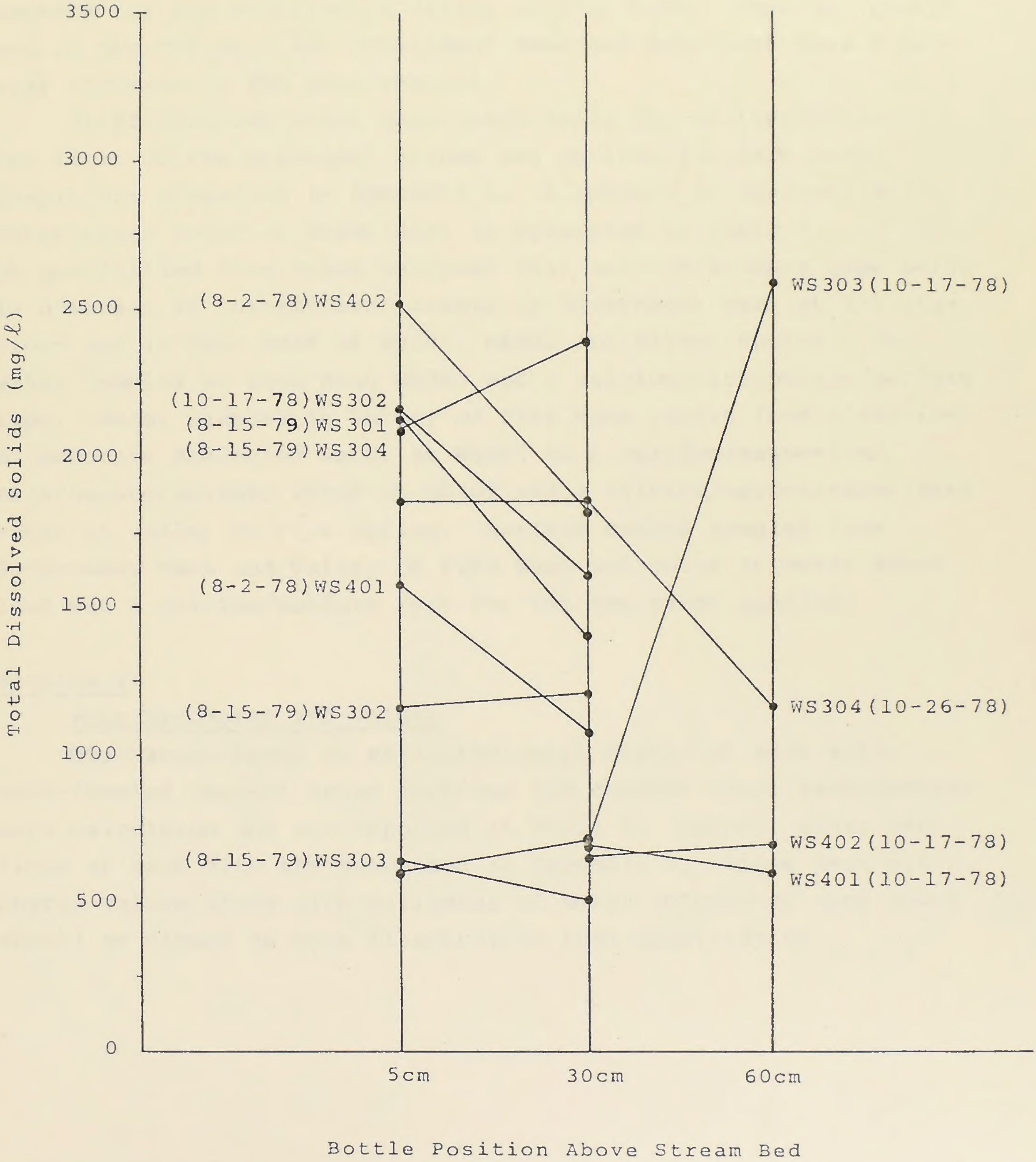

Figure 9: TDS vs. water depth at water quality samplers.

Water quality variation with location within the three basins for which data was available is illustrated in Figure 10. The TDS appears to change very little in the 2,000 ft (600 m) distance between the two stations in Valley of Fire Wash. However, analyses of the TDS data for Government Wash and Echo Wash show a general increase in TDS down-channel.

Stiff diagrams which show graphically the milliequivalents per liter of the principal anions and cations for each water sample are presented in Appendix A. A summary of analyses of water types based on these data is presented in Table 4. It can be generalized from these analyses that calcium/sulfate type water is dominant in intermittent events in Government Wash at all stations and in Echo Wash at WS301, WS302 and Bitter Spring. The water sampled at Echo Wash WS303 was a calcium/bicarbonate/sulfate type. Water samples in Valley of Fire Wash varied from a calcium/bicarbonate dominated water at WS401 to a calcium/magnesium/bicarbonate/sulfate water at WS402 and a calcium/magnesium/sulfate water at Valley of Fire spring. Surface runoff samples from Government Wash and Valley of Fire Wash collected at North Shore road was a calcium/sulfate type for the one event sampled.

Section 2

Peak Discharge and Volume

Discharges based on estimated water depths at each site, hand-leveled channel cross sections and channel slope measurements were calculated and are reported in Table 5. Channel cross sections at each site are presented in Appendix B. These peak discharge values along with estimates of total volumes of each event should be viewed as more illustrative than quantitative.

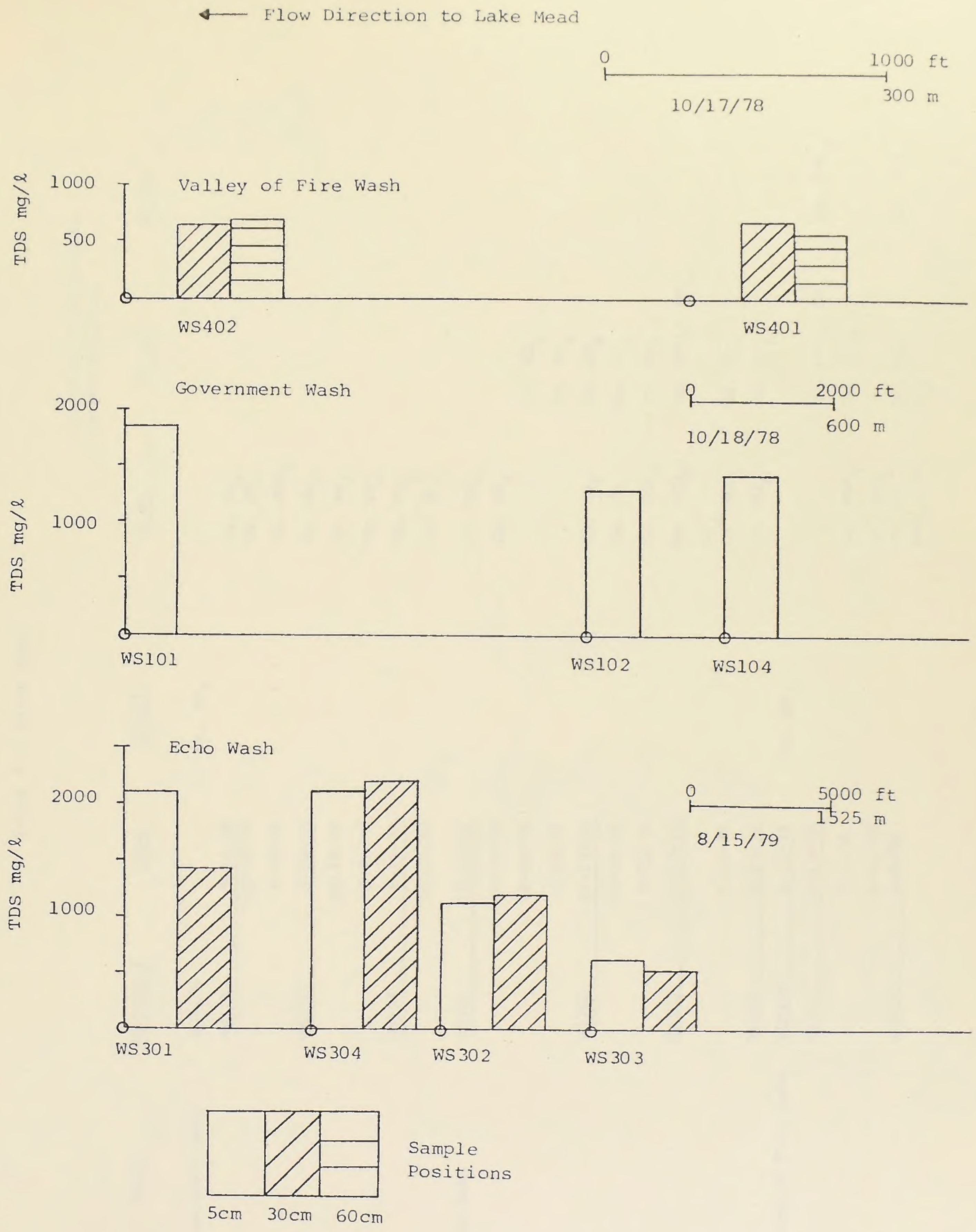

Figure 10: TDS variation with channel distance.

Table 4 : Water Type

				Principal constituents Sample Position		
Basin	Station #	Date	Runoff	5 cm	30 cm	60 cm
Government Wash	BLM100		Ca, SO_4			
	WS101	5-24-78		Ca, SO_4		
		10-18-78		Ca, SO_4		
		8-21-79		Ca, HCO_3		
	WS102	5-24-78		Ca, SO_4		
		10-18-78		Ca, SO_4		
		8-21-79		Ca, SO_4		
	WS104	5-24-78		Ca, SO_4		
		10-18-78		Ca, SO_4		
Echo Wash	WS301	10-17-78		Ca, SO_4		
		10-18-78		Ca, SO_4		
		10-26-78			Ca, SO_4	
		8-15-79			Ca, SO_4	
	WS302	10-17-78		Ca, SO_4	Ca, SO_4	
		10-26-78		Ca, SO_4	Ca, SO_4	
		8-15-79		Ca, HCO_3	Ca, SO_4	
	WS303	10-17-78		Ca, HCO_3, SO_4	Ca, HCO_3, SO_4	
		8-15-79		Ca, HCO_3	Ca, SO_4	
	WS304	8-15-79		Ca, SO_4	Ca, SO_4	
Valley of Fire Wash	BLM400	2-10-78	Ca, SO_4			
	WS401	10-17-78			Ca, HCO_3, SO_4	Ca, HCO_3
		8-2-78		Ca, HCO_3	Ca, HCO_3	
		8-21-79		Ca, HCO_3		
	WS402	8-7-78		Ca, Mg, HCO_3, SO_4	Ca, Mg, SO_4	Ca, HCO_3

Table 5 : Estimated Peak Flows

Peak Flows, $ft^3/sec/(m^3/sec)$

		Dates of field data collection							
Basin	Site	5-24-78	8-2-78	10-17-78	10-26-78	3-29-79	6-14-79	8-15-79	8-21-79
Government Wash	101	160 (4.48)		+368 (10.30)					2 (.06)
	102	240 (6.72)		+13 (.36)					2 (.06)
	104	180 (5.04)		+14 (.40)					13 (.36)
West End Wash	201	6 (.17)		+6 (.17)					
	202			13 (.36)					
Echo Wash	301			430 (12.04)	1140 (31.92)			65 (1.82)	
	302			+260 (7.28)	200 (5.6)			410 (11.48)	
	303			+1070 (29.96)	11 (.31)		11 (.31)	350 (9.8)	
	304			510 (14.28)	250 (7.0)			60 (1.68)	
Valley of Fire Wash	401	NI	54 (1.51)	710 (19.88)		<2 (<.06)		2900* (81.2)	3 (.08)
	402	NI	580 (16.24)	2640 (73.92)		<2 (<.06)		2100* (58.8)	**

+ water depth was between two bottles but no clear water mark. The discharge for the lowest bottle height was used.
* sampling station destroyed
** station not re-instrumented
NI not instrumented at the time of event

Approximations of peak discharge indicate that Valley of Fire Wash and Echo Wash had the highest peak discharges during the study with West End Wash having the lower peak flows. Analyses of data indicate that only once during the two years of record, related to the sample collection data of 10-17-78 and the probable event date of 9-14-78 and 9-15-78, that discharge was recorded in all four washes. Valley of Fire Wash had five recorded events, Echo Wash four, Government Wash three and West End Wash two. It should be noted that the values of over 1,000 ft^3/sec (30 m^3/sec) recorded for Valley of Fire Wash and Echo Wash stations are within reason, based on the basin area, channel cross sections, recorded water depths and probable velocities of 5 to 10 ft/sec (1.5 to 3 m/sec.).

The volume of water which discharges as a result of a flash flood event is difficult to predict without stage discharge relationships, which require fixed monitoring stations and numerous years of flow gaging to correlate stage and volume. A two-station section in Echo Wash was instrumented in the summer of 1979 with two inexpensive instrument shelters with event-starting Stevens Type F water level recorders (Figure 6). On 8-15-79 a flow event occurred which triggered both recorders, however, only the up-channel station recorded a stage-time relationship (Figure 11). It was also noted that the gaging house design allowed for considerable sedimentation, which made the stage record of limited value. A channel cross section constructed after the event is presented in Appendix B for completeness. The stage hydrograph presented does illustrate the rapid peaking of a flash flood event and the short duration. In this particular example two peaks are noted. The USGS has developed a method to estimate the volume of an event based on the peak discharge which basically uses a plot of volume vs. peak discharge (Aldridge, 1980, personal communication). Applying this method, volumes of intermittent events were calculated from the estimates of peak discharge data at each station (Table 6). Further summary of the data necessary to

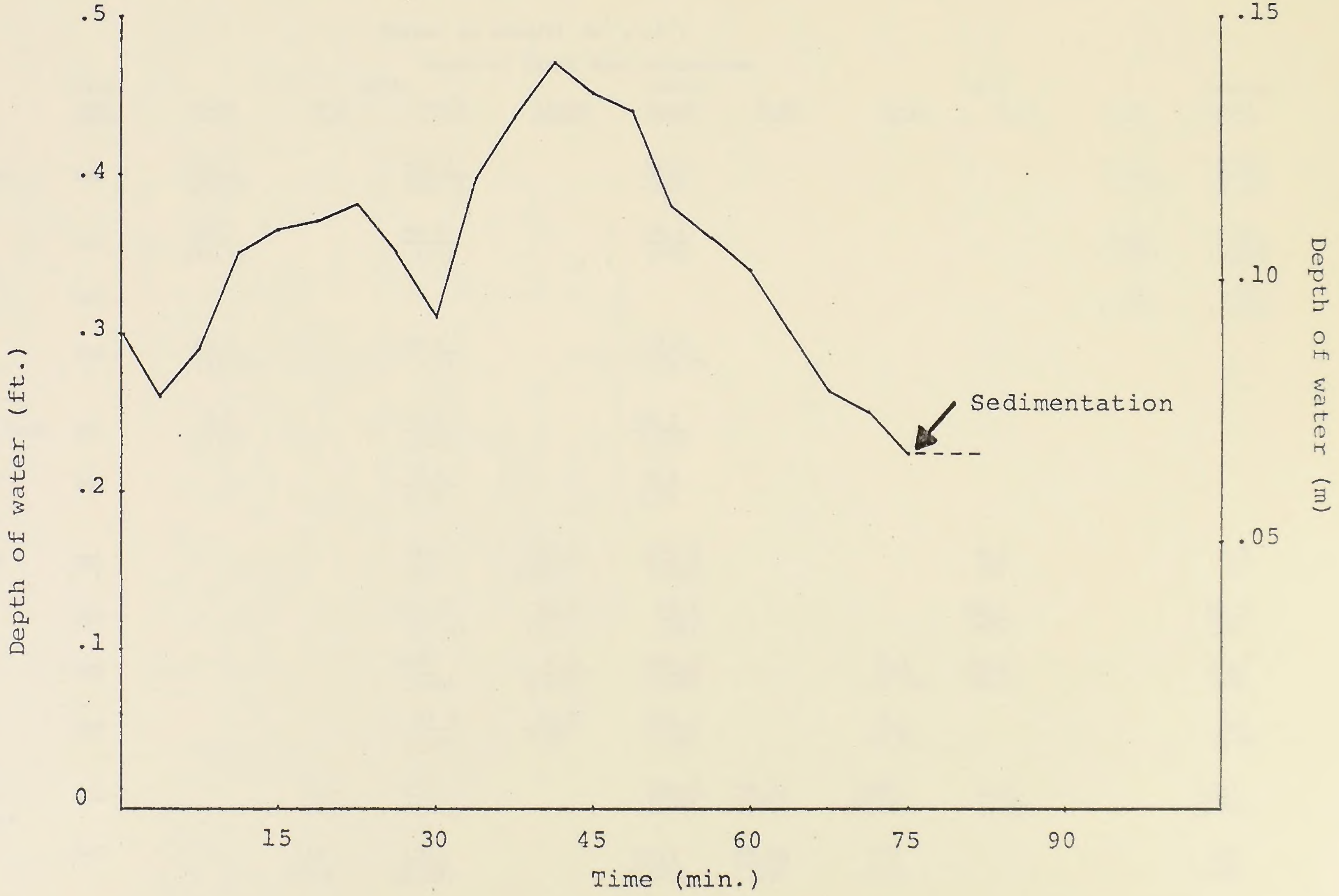

Figure 11: Stage hydrographs of intermittent flow event, Echo Wash, 8-15-79.

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Table 6: Estimated Volume of Water Per Intermittent Flow Event

Volume in acre/ft ($m^3 \times 10^3$)

Dates of field data collection

Basin	Site (WS)	1978 5-24	1978 8-2	1978 10-17	1978 10-26	1978 Yearly Total	1979 3-29	1979 6-14	1979 8-15	1979 8-21	1979 Yearly Total
Government Wash	101	16.2 (20.0)		+56.5 (69.7)		72.7 (90)				0.02 (.025)	0.02 (0.25)
	102	29.7 (36.6)		+0.4 (.5)		30.1 (38)				0.02 (.025)	0.02 (.025)
	103									.04 (.050)	.04 (.050)
	104	19.3 (23.8)		+0.4 (.5)		19.7 (24.3)					0
West End Wash	201	0.1 (.12)		0.1 (.12)		+0.2 (.25)					
	202			0.4 (.5)		0.4 (.5)					
Echo Wash	301			71.3 (88)	307.9 (380)	379.2 (470)			4.9 (6)		4.9 (6)
	302			+33.5 (41.3)	22.6 (29)	56.1 (70)			66.4 (82)		66.4 (82)
	303			+280 (346)	0.3 (.37)	280.3 (350)		0.3 (0.37)	52.4 (650)		57.7 (65)
	304			92.1 (114)	31.6 (39)	123.7 (150)		3.7 (4.6)			3.7 (4.6)
Valley of Fire Wash	401		3.2 (4)	151 (186)		154.2 (190)	<0.02 (.03)	1249 (1540)	0.04 (.05)		1249 (1540)
	402		112 (140)	1085 (1339)		1196 (1480)	<0.02 (.03)	770 (950)			770 (950)

calculate volumes of water leaving BLM lands is illustrated by utilizing the station farthest down-channel located on the BLM-NPS boundary in each basin:

Basin	Station	Volume of water ac/ft ($m^3 \times 10^3$) 1978	1979
Government Wash	WS101	72.7 (89.8)	0.02 (0.02)
West End Wash	WS201	+0.2 (0.25)	0 (0)
Echo Wash	WS301	379 (464)	4.9 (6.05)
Valley of Fire Wash	WS402	1,196 (1,477)	770 (951)

Analyses of this data shows that during 1978 an estimated total of 1,660 acre feet (2×10^6 m^3) of water left these four drainages tributary to the Colorado River as flash flood events. In 1979 the total was approximately 775 acre feet (9.5×10^5 m^3. The results of calculating salt loading to Lake Mead are given in Table 7. It was assumed that little additional salt pickup occurs down gradient from the last sampling point and that the volume of salt which reached the lake from BLM lands totally mix with the maximum lake volume, 2.62×10^7 ac/ft (3.2×10^{10} m^3). Comparison of annual salt load in tons to lake volume shows that flows from these basin events probably contributed less than 0.1 mg/l of salinity to the Colorado River system during the study period.

Section 3

Factors affecting quantity and quality results

The occurrence and distribution of precipitation, basin topography, geology and soils and vegetation influence the quantity

Table 7 : Salt Loading of Lake Mead

	Volume of water leaving the basin ac/ft $(m^3 x 10^3)$		Average TDS	Tons of Salt entering Lake Mead (metric tons)		Calculated increase in mg/ℓ of Lake Mead	
Basin	1973	1979	mg/ℓ	1978	1979	1978	1979
Government Wash	72.7 (90)	0.02 (.03)	2000	198 (178)	.05 (.045)	.006	1.4×10^{-6}
West End Wash	+0.2 (.25)	0	1270*	0.3 (.27)	0	8.4×10^{-6}	0
Echo Wash	379 (470)	4.9 (6)	1500	773 (696)	10 (9)	.02	.0003
Valley of Fire	1196 (1500)	770 (950)	1270	2065 (1860)	1330 (1200)	.06	.04
combined study area, principally BLM land				3,036 (2,700)	1340 (1209)	.08	.04

*assumed similar to Valley of Fire

and quality of events occuring within the study site. Available data were reviewed and an attempt to relate each component to observed flow qualities and quantities was made.

Precipitation

Nine precipitation stations are present near the four study sites (Figures 7A and 7B). The station at Las Vegas has been in operation since 1937, Sunrise Manor since 1951 and the remaining stations since 1975. Las Vegas is the only station at which rainfall intensity data is available; all other stations have non-recording rain gages. A plot of the annual precipitation at the Las Vegas station is shown in Figure 12. Yearly data form 1975 to 1978 are plotted for the Las Vegas Station and the four stations more closely associated with the four drainage basins (Figure 13). Review of these data show that the 1978-1979 study period coincided with wetter-than-average years and that similar above average years had occurred in four out of the last 42 years. Analyses of Figure 13 data indicate that Las Vegas yearly trends correlate with recorded rainfall at the other stations. Yearly totals for all nine stations from 1975 to 1979 are detailed in Appendix C. Records of the amount of precipitation at each station when intermittent flow events were recorded were reviewed in comparison with rainfall intensity data for the Las Vegas station. No clear relationship between station location, amount, Las Vegas data and the quantity or quality of recorded events was evident. Detailed statistical analyses may identify a relationship; however, it was felt that such an effort was beyond the reconnaissance nature of the study.

Topography and Physiography

General basin characteristics are presented in Tables 8 and 9. Echo Wash is the largest of the washes in terms of drainage area, channel length, maximum width and relief. Valley of Fire was second in size. Government and West End Washes are third and

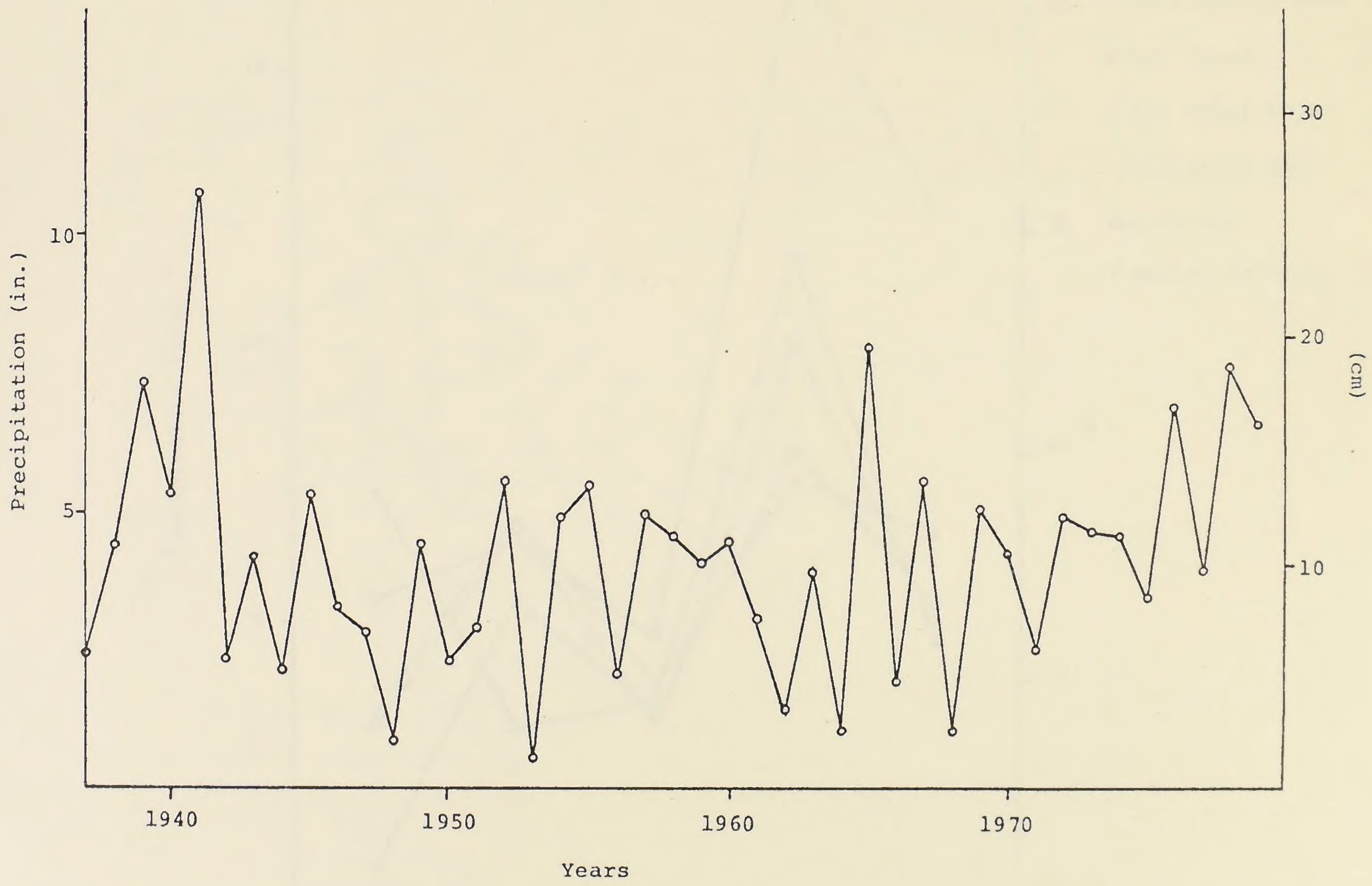

Figure 12: Annual precipitation at the Las Vegas NOAA station, 1937 to 1979.

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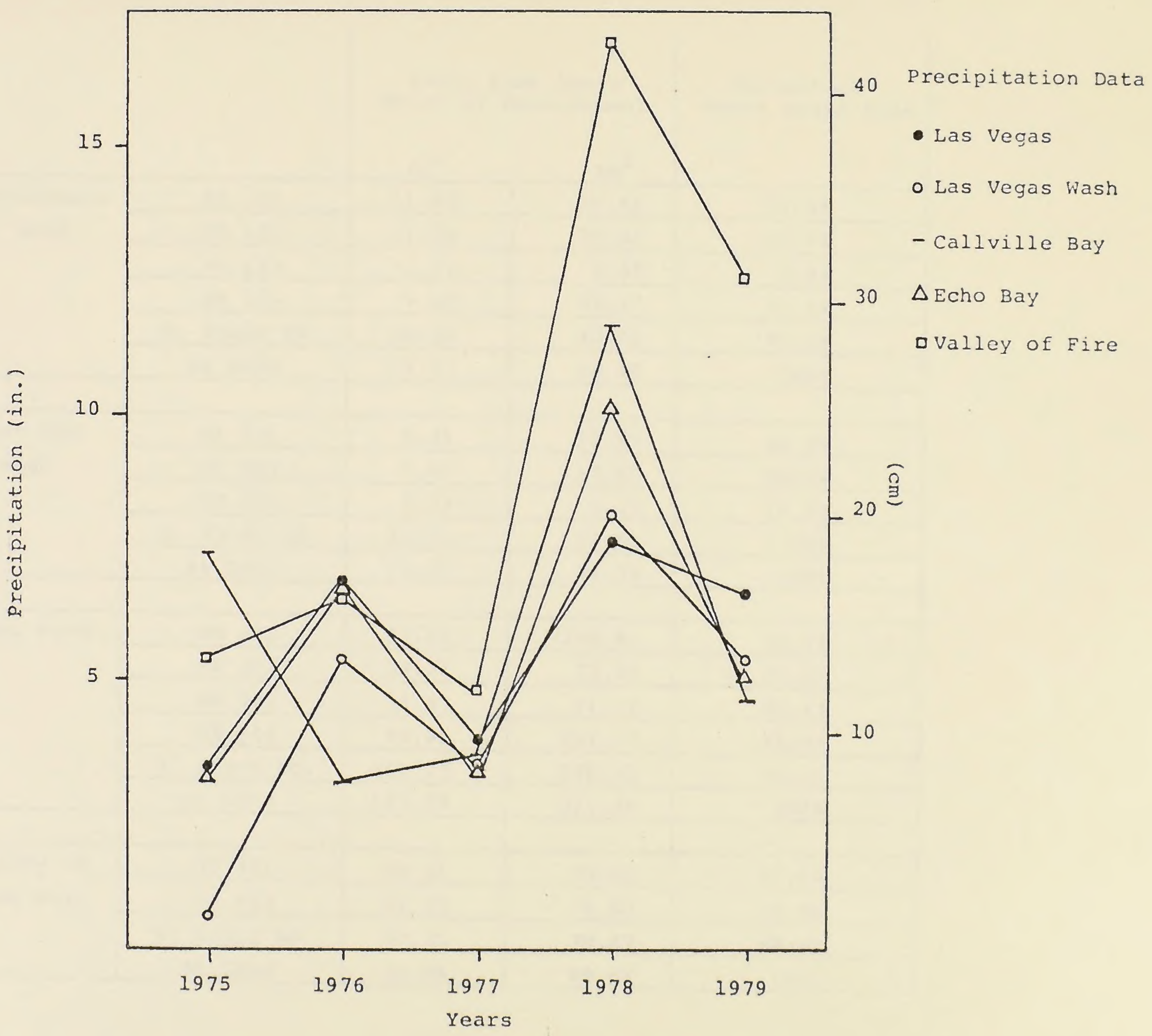

Figure 13: Annual precipitation at the Las Vegas NOAA station and four ranger stations in the vicinity of the study area, 1975 to 1979.

Table 8: Basin Areas

		Basin Area Above Point of Measurement		Percent of Total Basin Area
		Mi^2	Km^2	
Government Wash	WS 101	11.88	30.89	63.3%
	WS 102	11.36	29.54	60.5%
	WS 103	1.02	2.65	5.4%
	WS 104	9.68	25.17	51.6%
	N. Shore Rd.	16.39	42.61	87.5%
	At Lake	18.77	48.80	100%
West End Wash	WS 201	6.91	17.97	45.2%
	WS 202	5.65	14.69	36.9%
	WS 203	2.59	6.73	16.9%
	N. Shore Rd.	12.53	32.58	1.90%
	At Lake	15.30	39.78	100%
Echo Wash	WS 301	97.89	254.51	79.2%
	WS 302	28.21	73.35	22.8%
	WS 303	35.07	91.18	28.4%
	WS 304	96.95	252.07	78.5%
	N. Shore Rd.	103.23	268.40	83.5%
	At Lake	123.56	321.26	100%
Valley of Fire Wash	WS 401	28.31	73.61	81.9%
	WS 402	28.78	74.83	83.3%
	N. Shore Rd.	30.72	79.87	88.9%
	At Lake	34.56	89.86	100%

TABLE 9 : Drainage Basin Characteristics

Basin	Area mi^2 (km^2) Total	Area mi^2 (km^2) ALSP*	Channel Length ft (m) Total	Channel Length ft (m) ALSP	Mid-Basin Channel Scope**	Max. Basin Width ft (m)	Basin Relief*** ft (m)
Government Wash	18.77 (48.05)	11.88 (30.41)	44,000 (13,400)	38,000 (11,600)	0.02	13,000 (4,000)	1,280 (390)
West End Wash	15.30 (39.17)	6.91 (17.69)	43,000 (13,100)	22,000 (6,700)	0.03	15,000 (4,600)	2,000 (610)
Echo Wash	123.56 (316.42)	97.89 (205.60)	85,000 (25,900)	69,000 (21,000)	0.02	7,000 (2,100)	2,880 (880)
Valley of Fire Wash	34.56 (88.47)	28.78 (73.68)	51,000 (15,500)	42,000 (12,800)	.02	2,100 (640)	1,680 (510)

*ALSP = above lowest sampling station, BLM-NPS Boundary

**Mid-Basin Channel Slope = slope of the channel calculated for a section near the middle of the basin - reflects general overall channel slope.

*** 1200 ft. (366m) used as lake elevation

fourth in overall size, respectively. When this ordering of basin size is compared with the occurrence of events in each basin and calculated peak discharges (Table 5) it is noted that Valley of Fire Wash had the most recorded events and the largest peak flows. The only generalization which can be made related to basin topography and the occurrence and quantity of water is that the larger basins had more frequent events and higher peak flows that the smaller basins. Utilizing only basin area as a criteria from which to generalize appears unreliable based on the limited data. Even though the Valley of Fire basin has three times less area than Echo Wash above the BLM-NPS boundary stations, it had almost 5 times higher peak flows when washes were flowing.

Geology and Soils

The general regional geology for the area was condensed from work by Longwell _et al_ (1965) and is presented in Figure 3. The area is considered structually complex, though for the sake of clarity the structure of the area was not presented. The principal geologic formations present in the four study sites are as follows:

Study Site	Principal Geologic Units Present*
Government Wash	Tmc, TKg
West End Wash	Tv, TKg, Pzc
Echo Wash	TKg, Pzc, Qal, Tmc
Valley of Fire Wash	Ja, Trcm, Tmc

*See legend of Table 1 for explanation

A Third-Order soil survey of the area was undertaken by the Soil Conservation Service (SCS) and the BLM. Partial data on the soil types were available at the preparation of this work. A list of the principal soil types found in each basin and a description of the soils is presented in Appendix D. A reproducable soil map and soil chemistry data were not available at the time this report was prepared.

The geologic setting and soil types in each basin will have an effect on the quantity and quality of flash flood events. The hydrologic properties of materials were not available; however, parent material exposed in the basins such as the Muddy Creek Formation (Tmc), Gale Hills Formation (TKg), Muddy Peak limestone (Pzc), Moenkopi-Chinle Formations (Trcm) and Aztec sandstone (Ja) would generally have low infiltration capacities. Weathered sandstone portions of some of these units and the alluvium (Qal) unit would have higher infiltration capacities. Soil infiltration capacities within the basins most likely vary inversely with the clay content. Quantity and geology-soil relationships cannot be derived with available data.

In addition to the geology and soils information, transects within each basin were instrumented with eolian material (dust) collectors. An eolian material accumulation study was developed on the idea that wind blown material may collect on the basin floor, in the channels and on channel slopes which would provide a source of soluble material for flow events, thus influencing water quality. The information collected from the transects was grouped by zones of accumulation as shown in Figure 8. Table 10 summarizes the average of results of a total 160 analyses of individual samples to determine the average volume of soluble material which collects per square foot per day. Analyses of results indicated that Valley of Fire Wash basin had the highest rates of accumulation and West End Wash the lowest rate over all zones.

Table 10 also includes an unweighted average of the listed rates for the study area by zone of accumulation. Detailed map information was not available to determine the areas within each basin which corresponds to the zone of accumulations. Based on field estimates less than 10% of the basin area would be included in Zones II and III and over 90% of the basins would be included in Zone I. The average accumulation rate of 10 mg/ft^2d (108 mg/m^2d) is considered conservative yet was used to calculate the annual accumulation of soluble eolian material over the basin

Table 10: Average Rates of Soluble Material Accumulation by Zone

	Zone of eolian accumulation average rates in mg of soluble material per ft^2 per day (mg/m^{3}d))		
Basin	I	II	III
Government Wash	12 (129)	11 (118)	9 (97)
West End Wash	6 (64)	5 (54)	---
Echo Wash	9 (97)	12 (129)	12 (129)
Valley of Fire Wash	14 (150)	19*(204)	19*(204)
Study Area	10 (108)	11 (118)	12 (129)

*Only one sample

and reservoir.

Gross chemical analyses of one set of dust samples was performed and results are given in Appendix E. Results of analyses of this data after constructing Stiff diagrams (Appendix E) are given in Table 11. Comparison of this data with Table 4 indicated that the Zone III soil type in Government Wash most closely parallelled event water quality type. However, the remaining soil types show Na^+ + K^+ as the principal cation combination associated with the bicarbonate and sulfate anions. It appears that generally the eolian material which is readily available for solution probably contributes to the overall event water quality; however, other factors such as bank erosion of gypsic soils most likely has a more significant effect.

The effect of eolian material on water quality may be more important as a source of salt to Lake Mead by direct entry. If it is assumed that a rate of 10 mg of soluble material collects per day per square foot over the entire four basin study area then over 21,000 tons (18,900 metric tons) of soluble salts would accumulate per year. In actuality this does not happen within the basin because winds and flows continually redistribute any accumulation of material. The possible contribution to the salinity of Lake Mead from direct entry of wind blown material has not been documented. It can be illustrated, however, if the surface area of Lake Mead is utilized, 229 mi^2 (586 km^2), and a rate of 10 $mg/d/ft^2$ is used, it can be shown 25,670 tons (23,100 metric tons) of soluble salt may enter the lake as eolian material annually. This would convert to an increase in TDS of 0.72 mg/l at Hoover Dam if complete mixing is assumed.

Section 4

Extrapolation of Salt Loading Analyses

Extrapolation of salinity loading data beyond the individual study basins was intended to be illustrative. Salinity loading from areas of ephemeral drainages tributary to Lake Mead and Lake

Table 11: Soluble Material Type

Basin	Zone I	Zone II	Zone III
	Principal ionic constiuents of soluble material		
Government Wash	Na+K, Ca, HCO_3	Na+K, SO_4	Ca, SO_4
West End Wash	Na+K, HCO_3	Na+K, Ca, SO_4	Na+K, Ca, SO_4
Echo Wash	Na+K, Ca, SO_4	Na+K, Ca, SO_4	
Valley of Fire Wash	Na+K, HCO_3, SO_4	Na+K, SO_4	Ca, SO_4

Mohave was attempted based on study data and the fact that basins are similar in character to those in the study area. An approximation of the basin area over which to apply salt loads is shown in Figure 14. The area includes the basins immediately adjacent to the reservoirs and excludes the Virgin and Moapa River drainages and the upper portions of major washes such as Detritus Wash.

Numerous assumptions have already been incorporated in calculations intended to quantify the contribution intermittent flow events and wind blown material have on the salt loading of the Colorado River. Generally, assumptions have been conservative in nature; i.e., using minimum water level and TDS values when calculating salt loading and assuming total mixing in the reservoir at maximum capacities.

The 1979 rate of salt loading calculated for the study area was also utilized in an attempt to remain conservative. It is realized that this rate may likely be high as data were collected in a wetter-than-normal period. However, other data were not available. As a result, a salt loading rate of 6.9 tons/mi^2 (2.4 metric tons/km^2) was applied over a total area of 2,780 mi^2 (7,100 km^2) of mainstream drainage area. Using these numbers, it was calculated that 19,180 tons of salt may be added to the Lake Mead and Lake Mohave system. When this amount of salt is compared to the combined storage capacity of the two reservoirs and total mixing is assumed, it can be shown that the TDS at Davis Dam may increase by 0.50 mg/l as a result of annual intermittent flow salinity loading.

A similar calculation, assuming eolian material accumulation rates for the surface areas of Lake Mead and Lake Mohave are equal, shows 0.76 mg/l of TDS at Davis Dam could be attributable to dissolution of wind blown material entering the lake system over the surface of these two reservoirs.

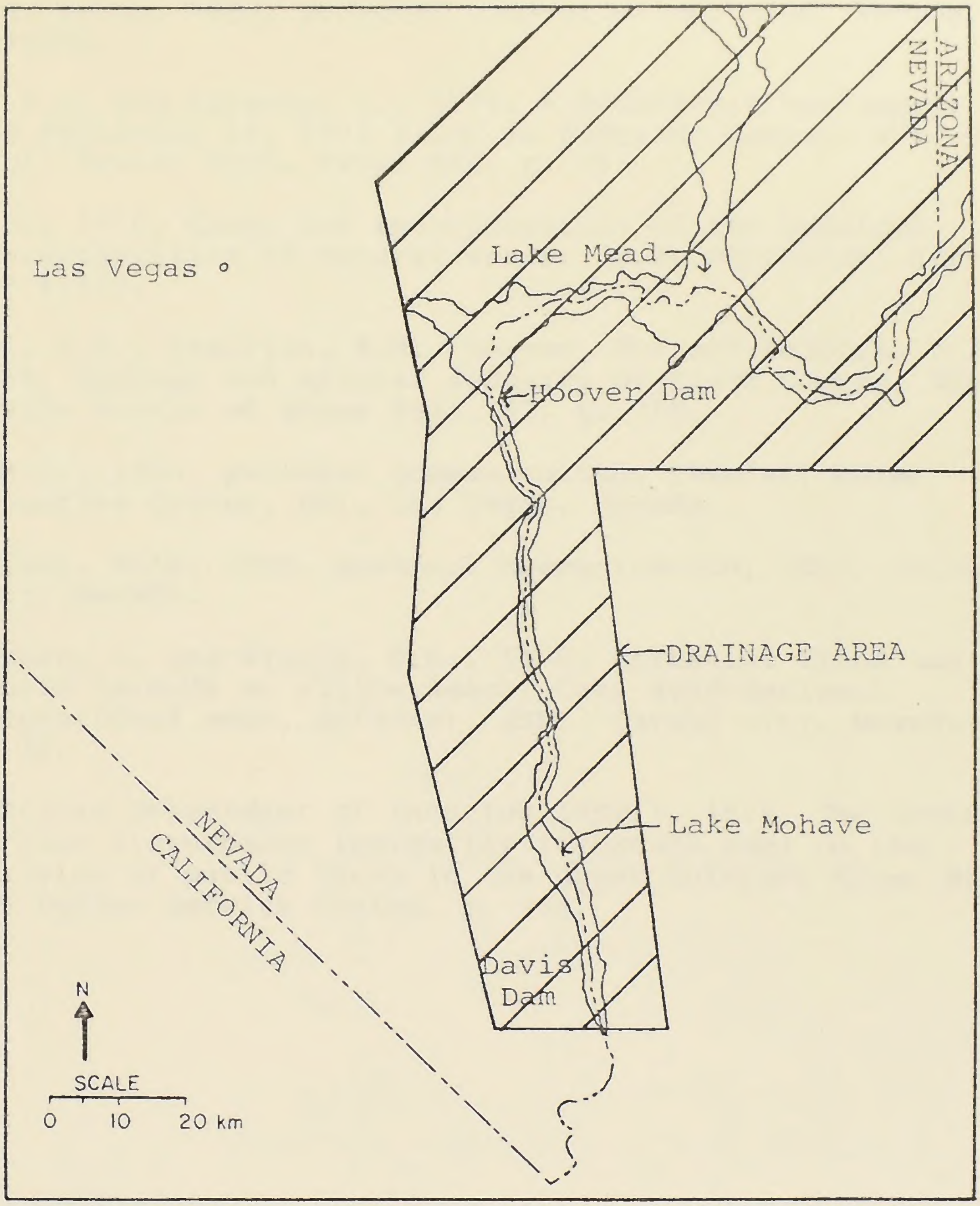

Figure 14: Drainage area for extrapolation of salt loading analyses.

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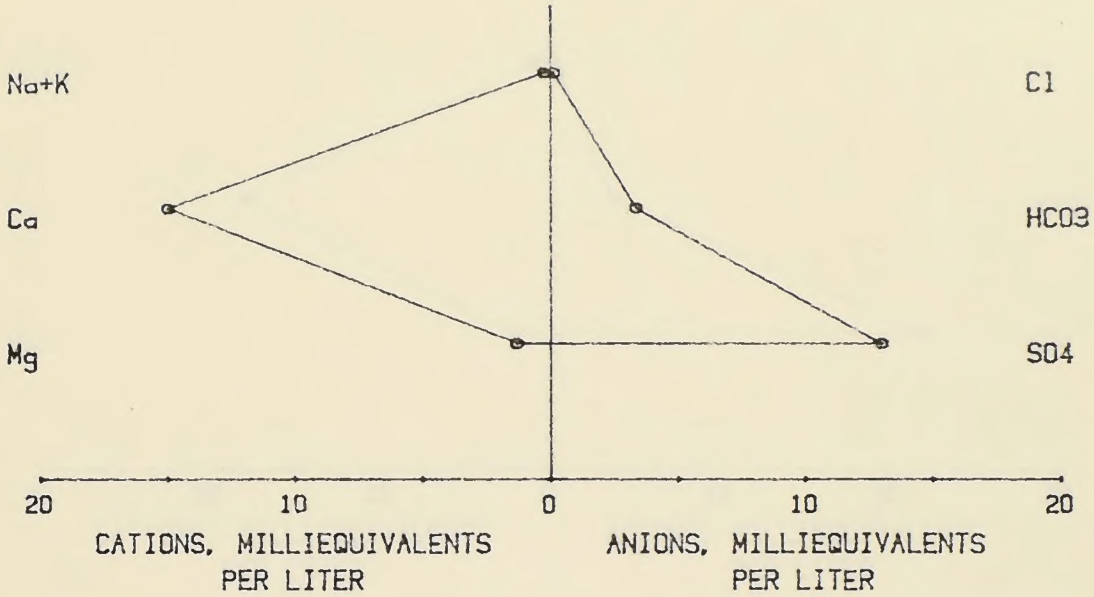
APPENDIX A

Stiff Diagrams of Water Quality Data

1. Diagrams are ordered as data is listed in Table 3.
2. If one or more principal ion was not reported, diagrams were not prepared.

SAMPLE BLM 100, 0 cm BOTTLE, 2-10-78



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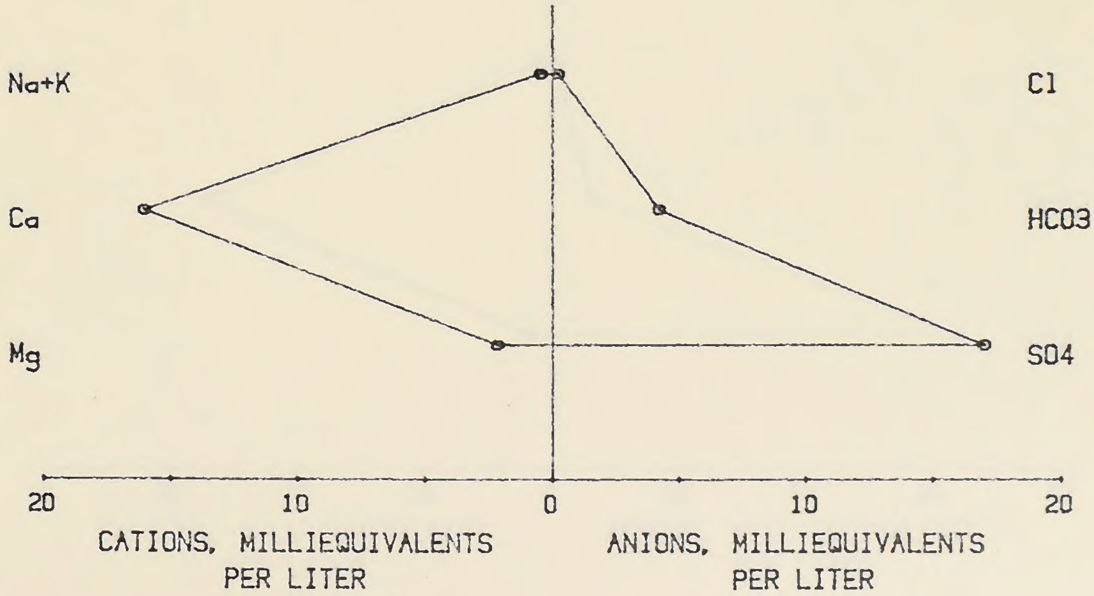

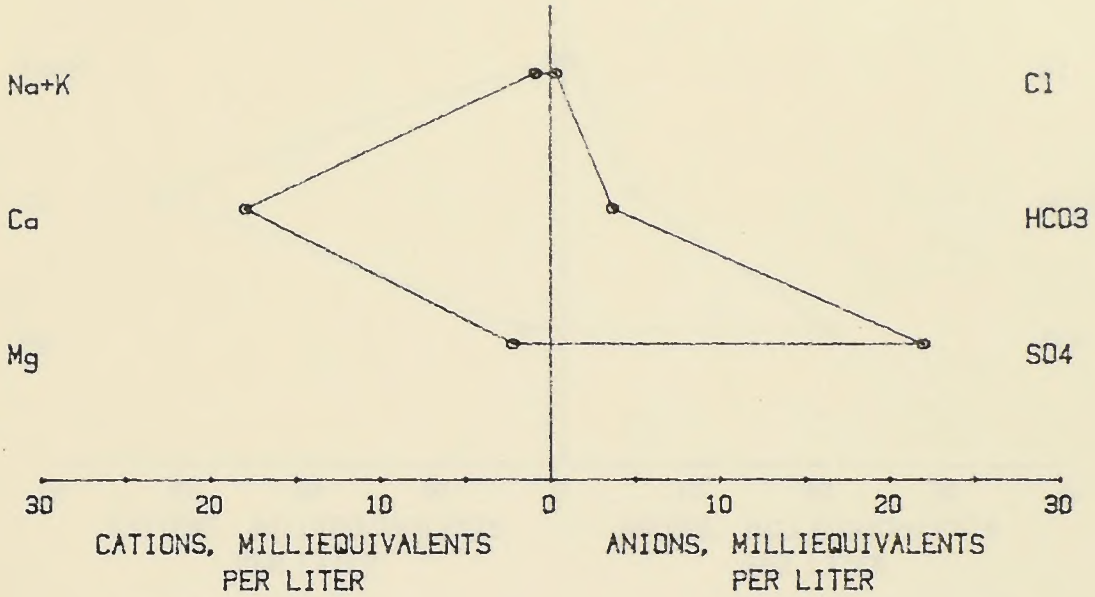
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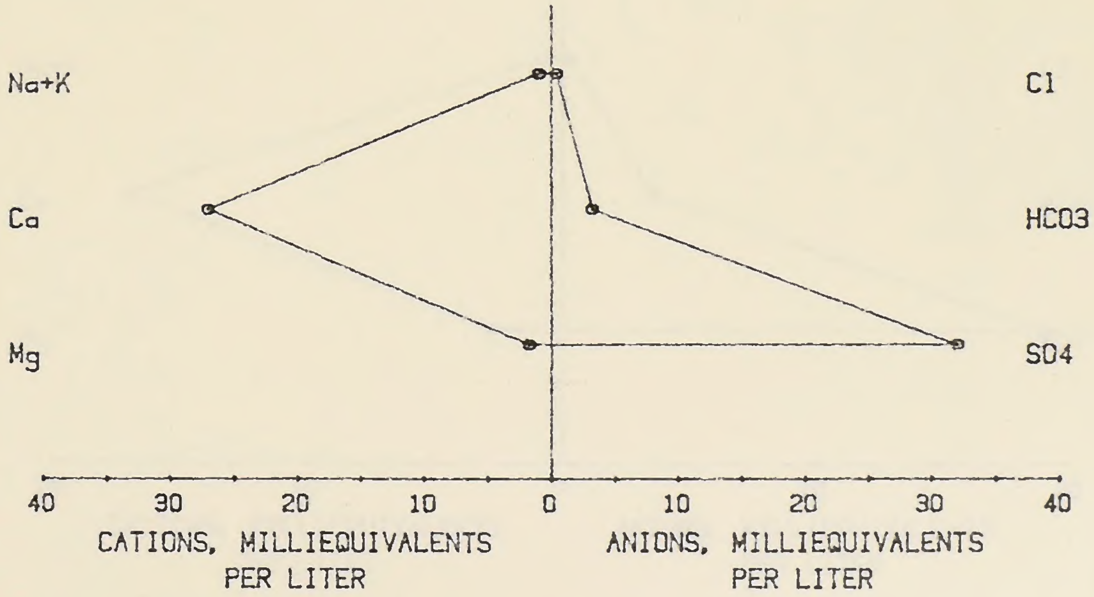
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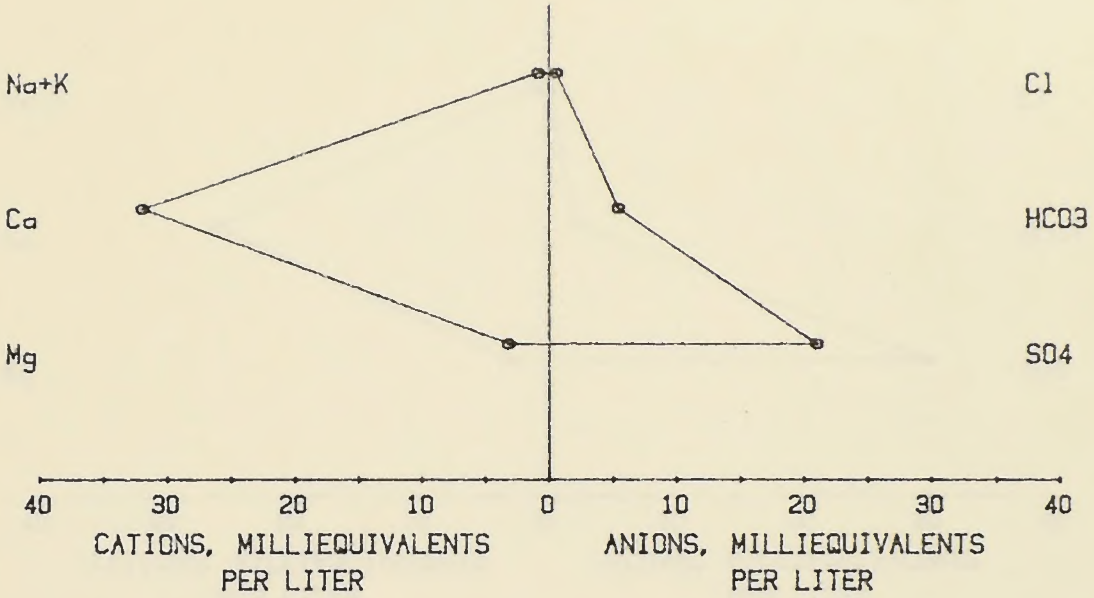

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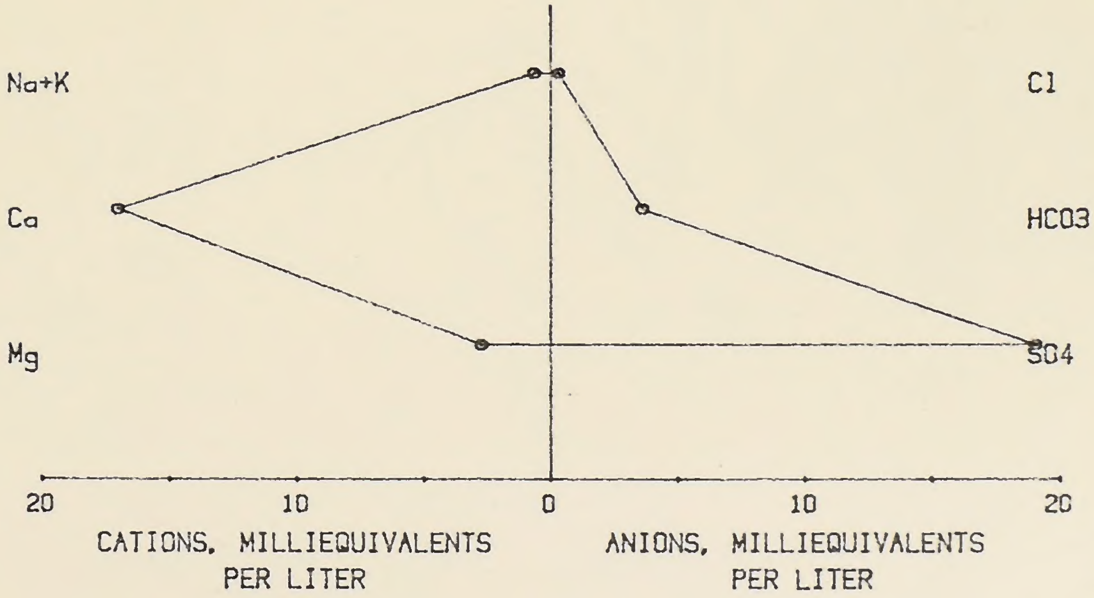

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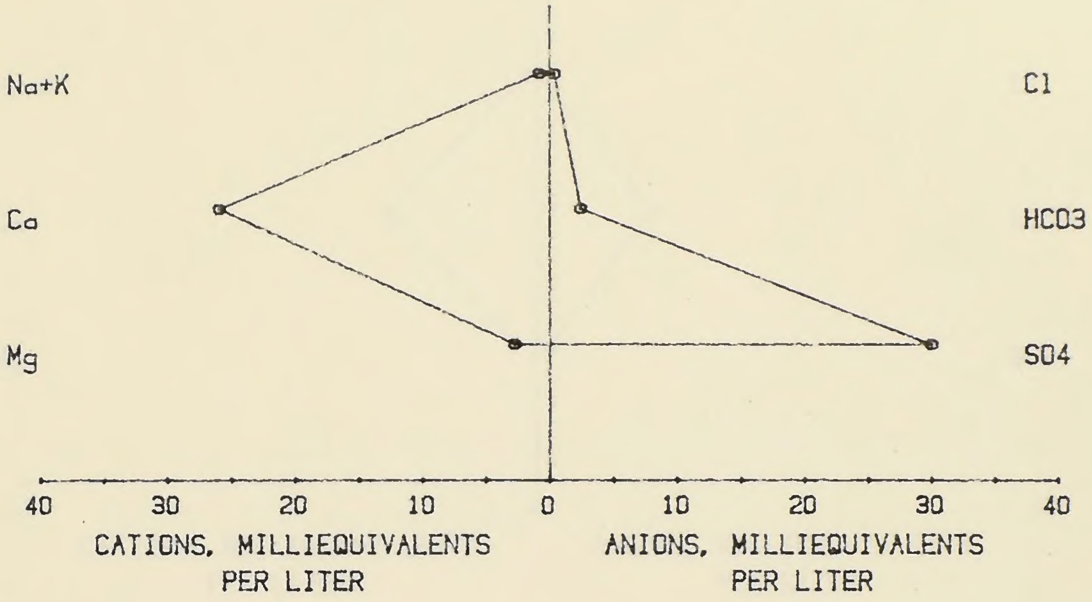

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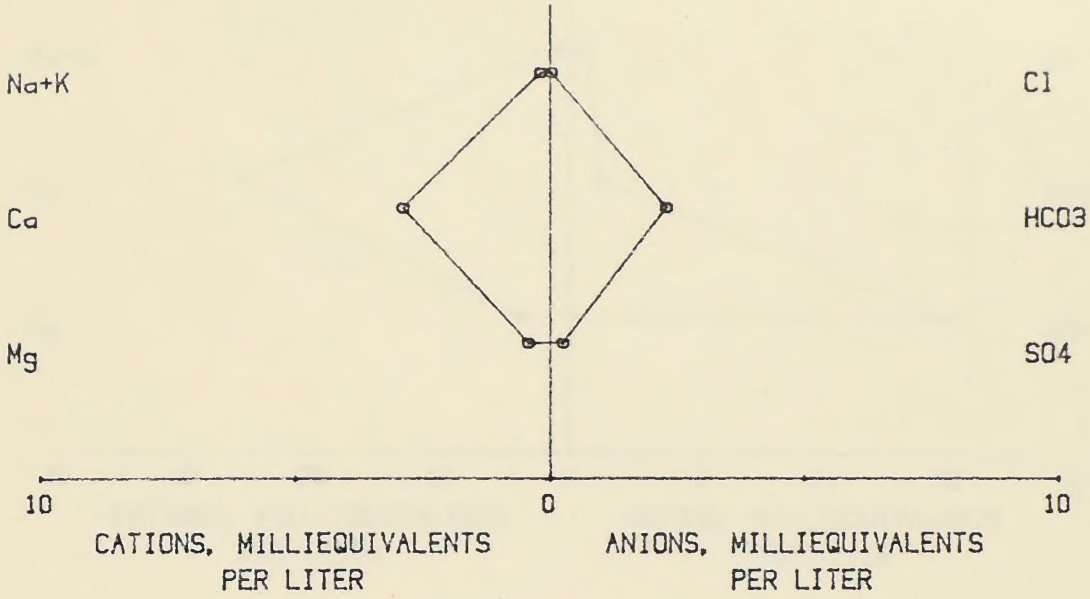

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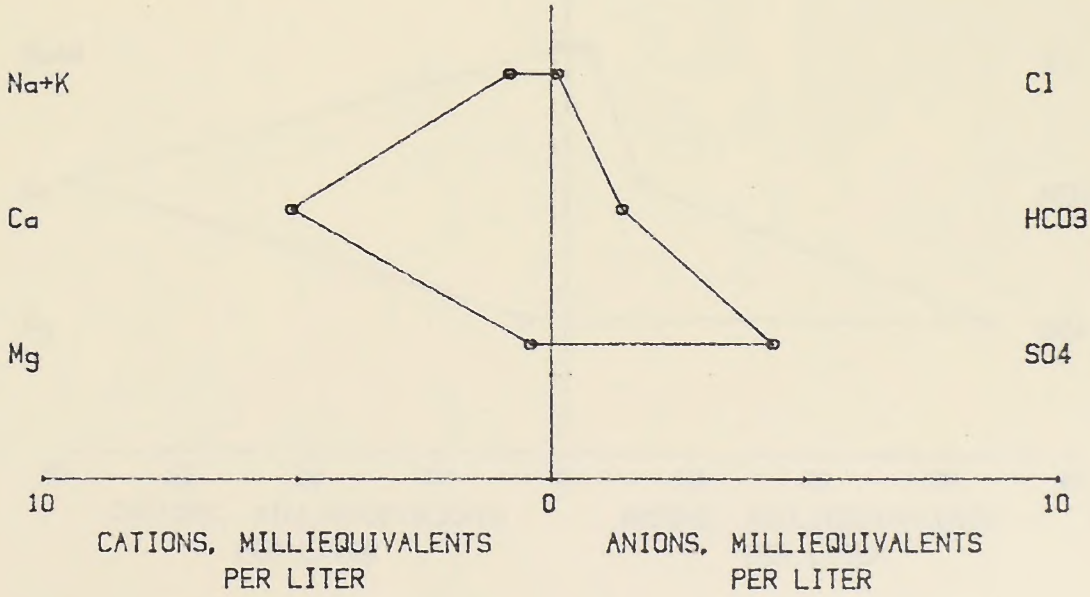

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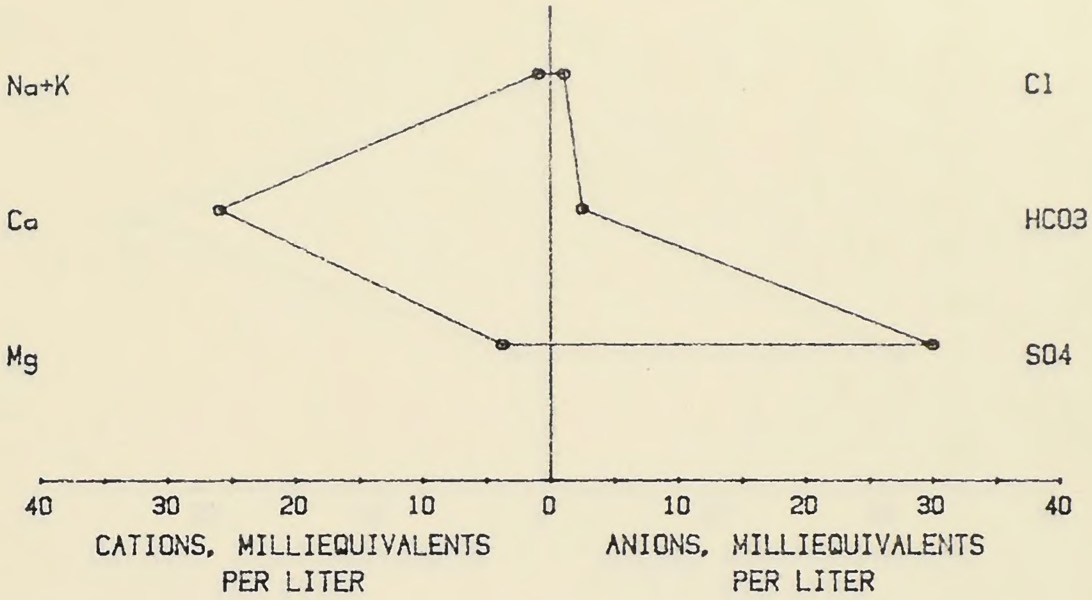

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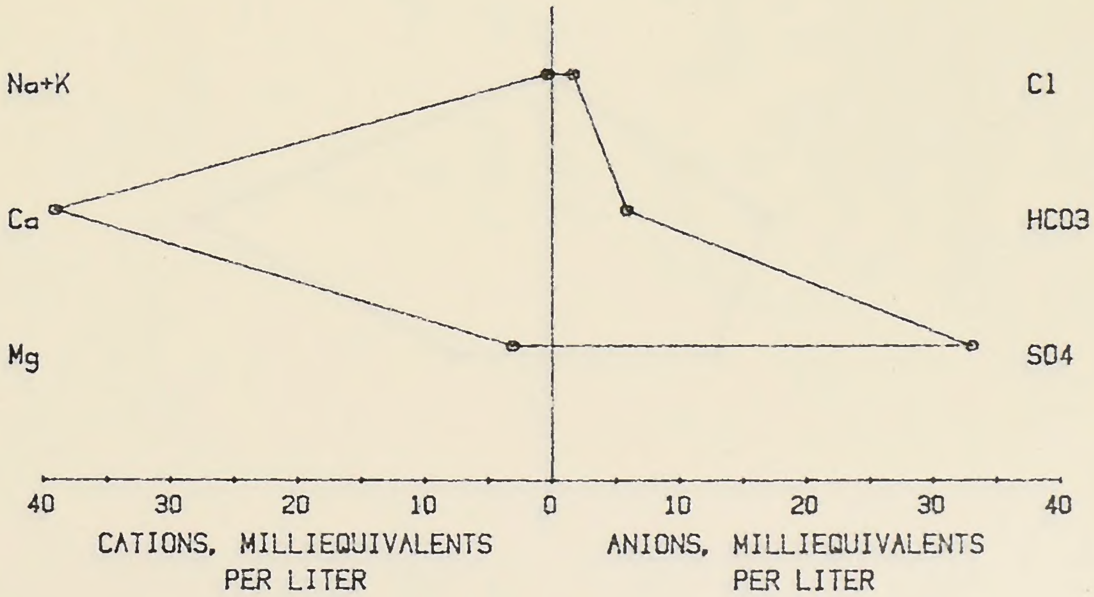

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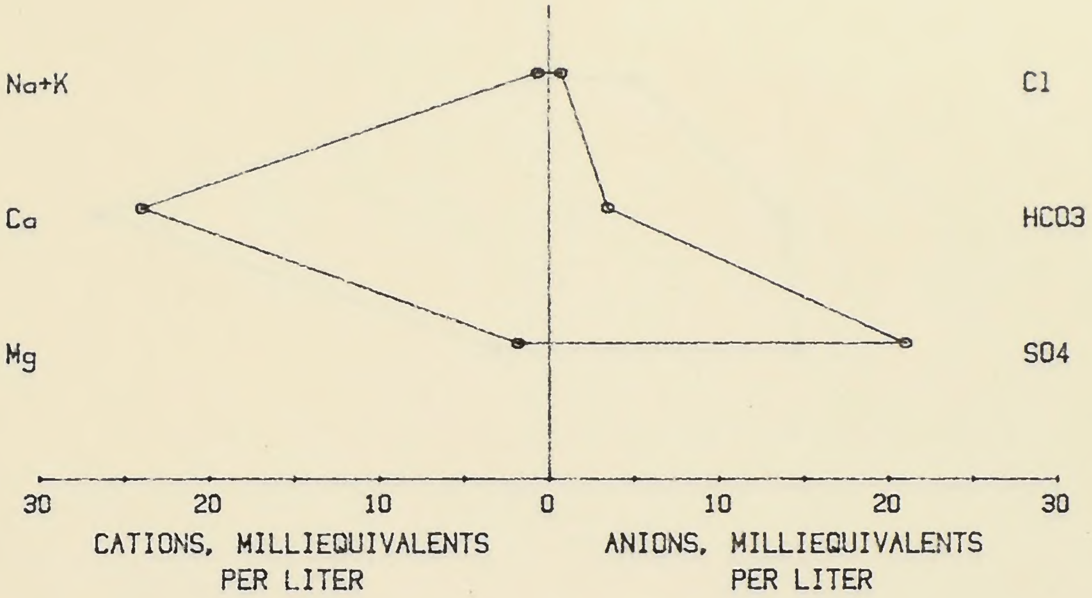

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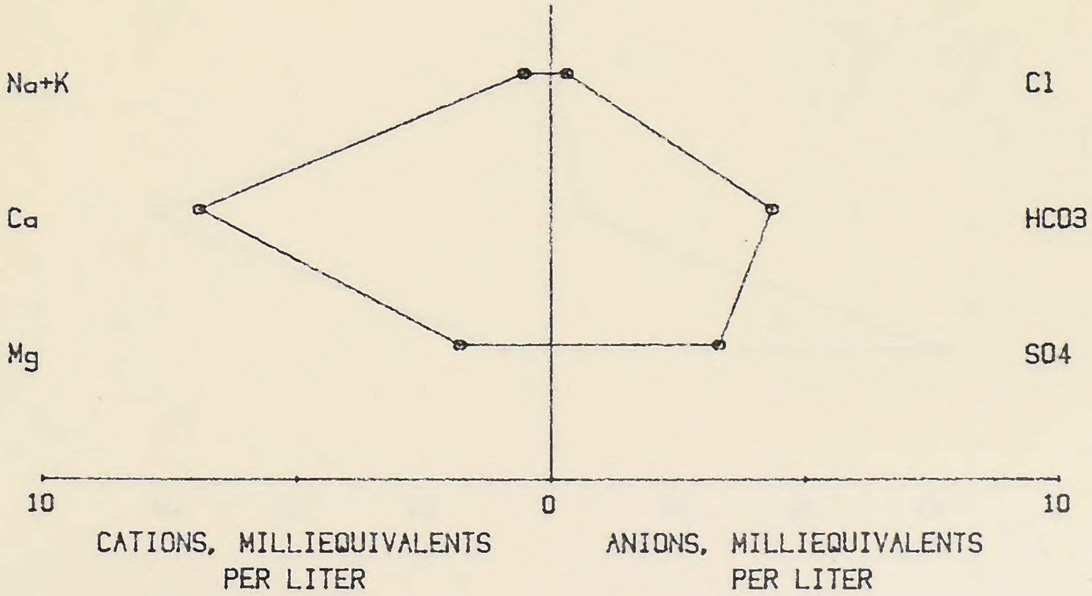

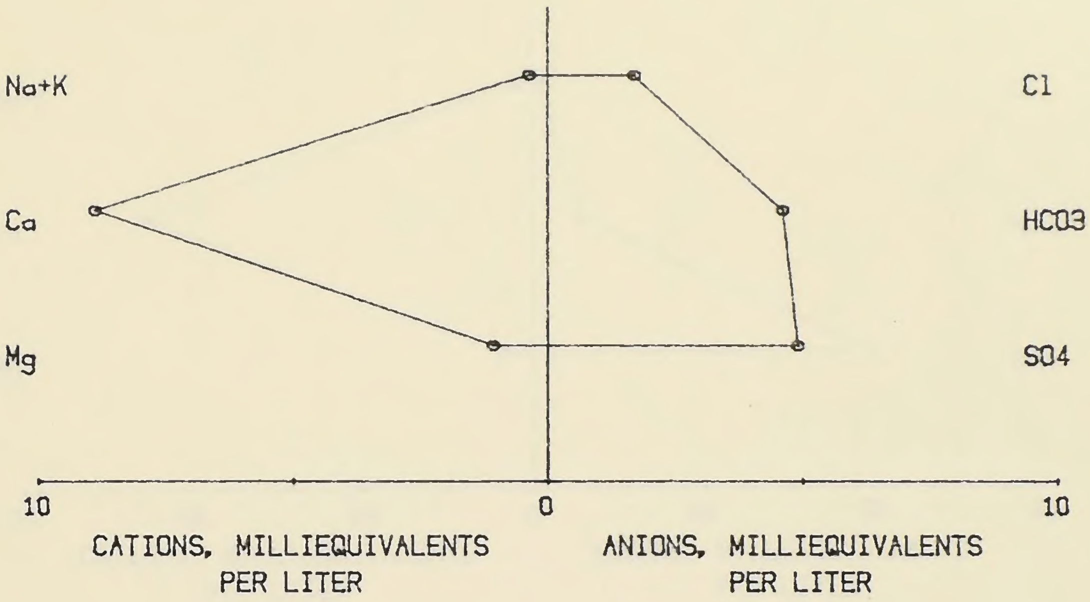

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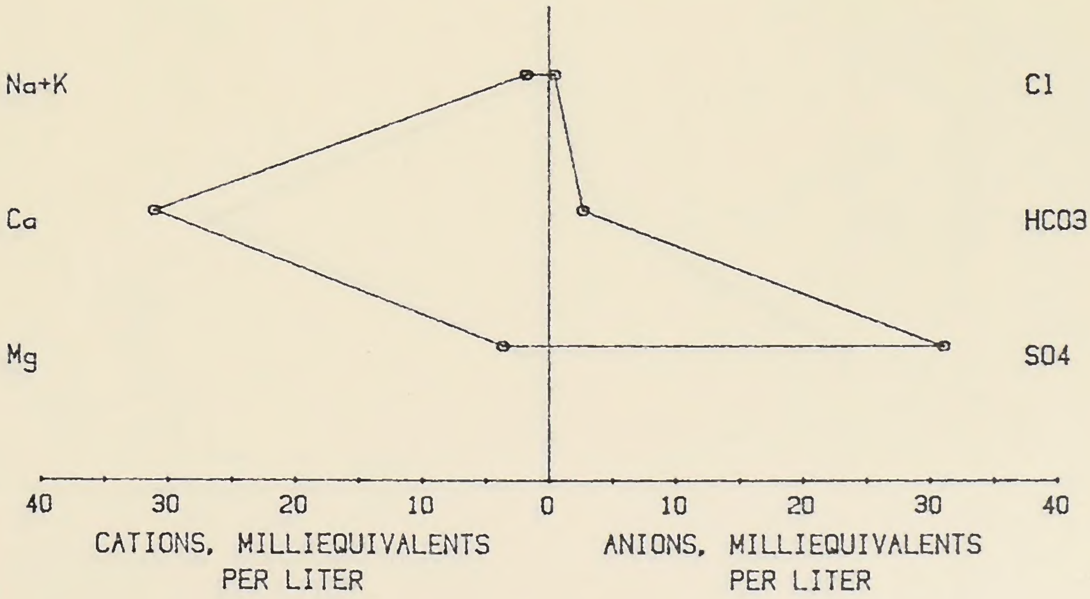

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[illegible]

[illegible]

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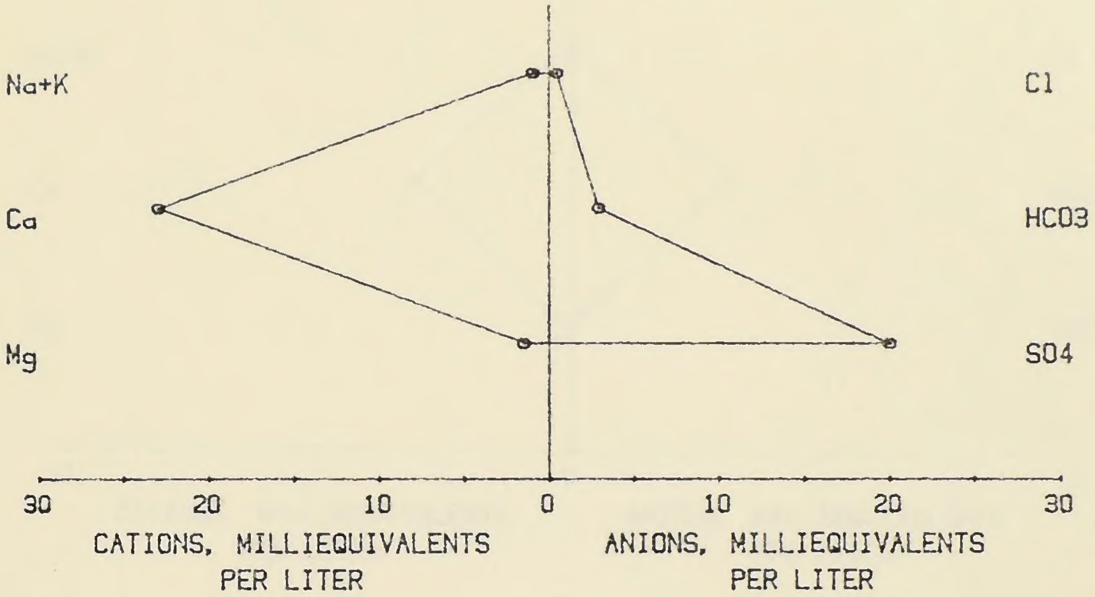

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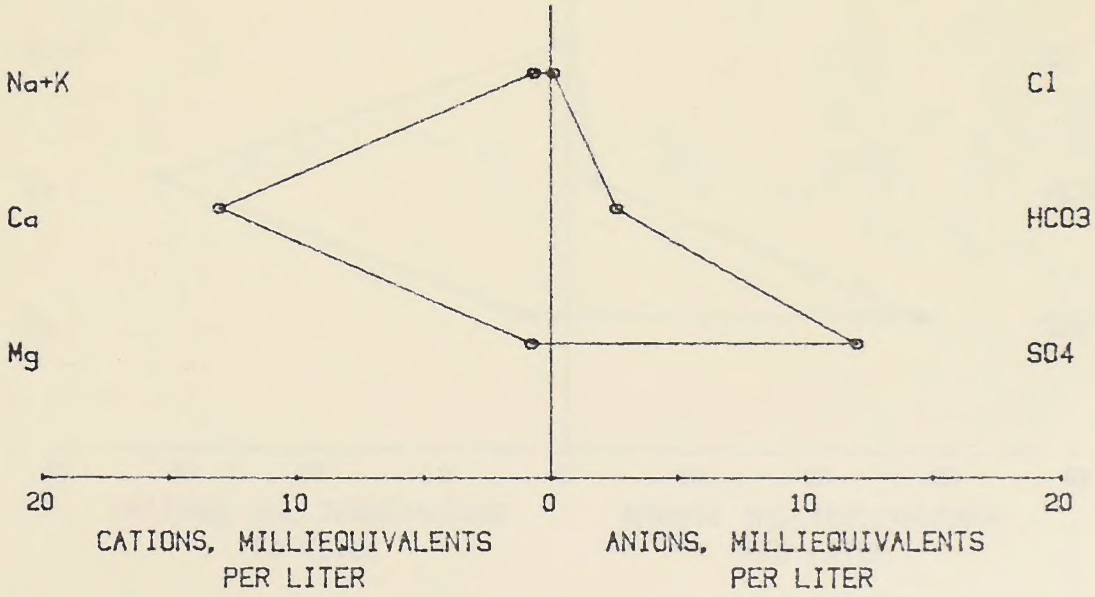

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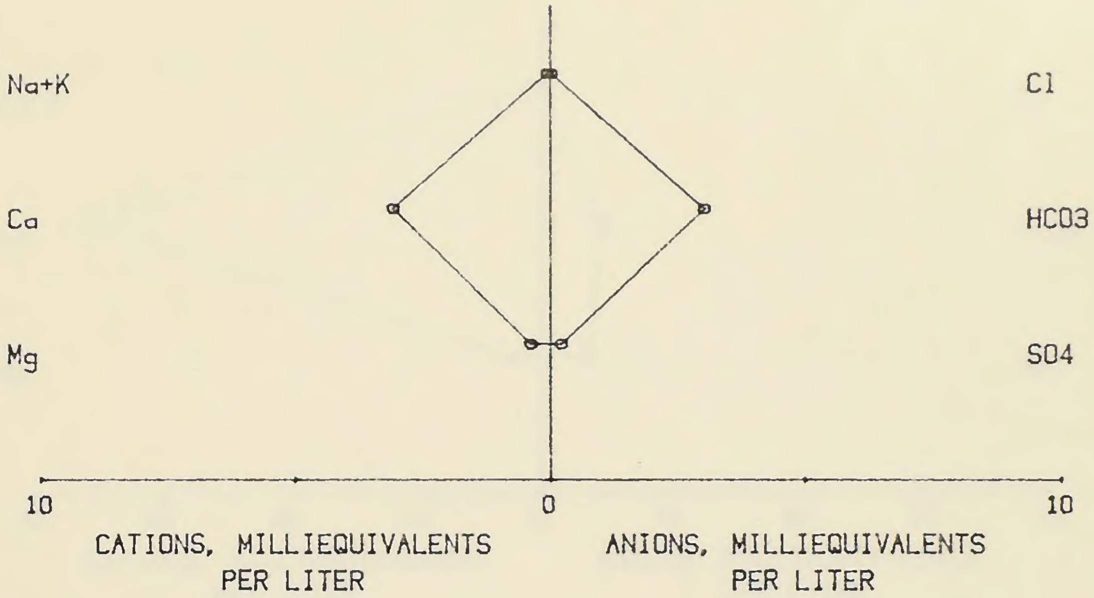

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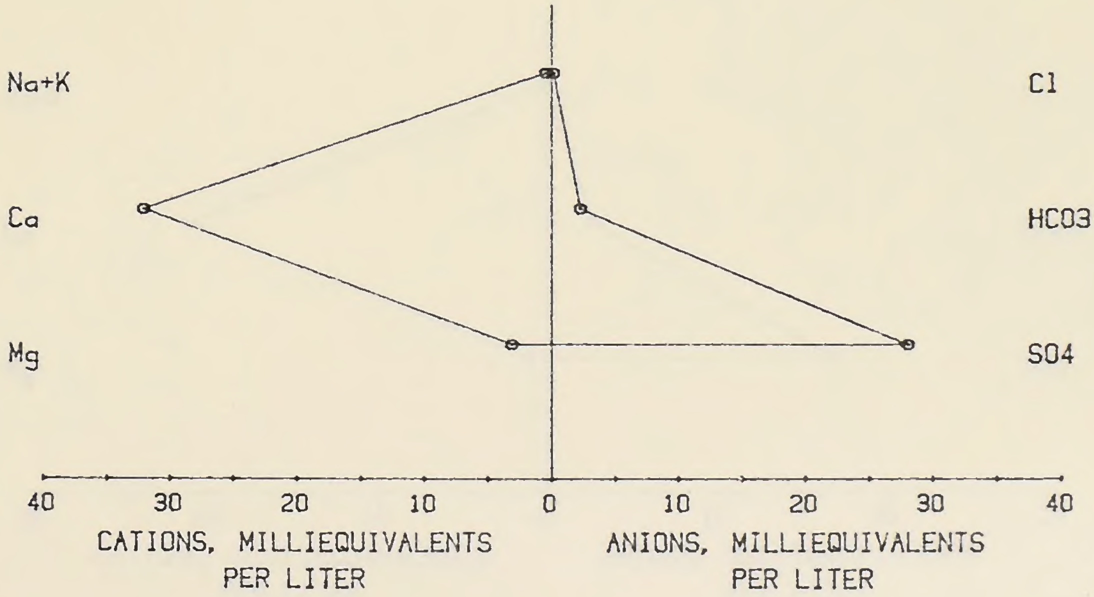

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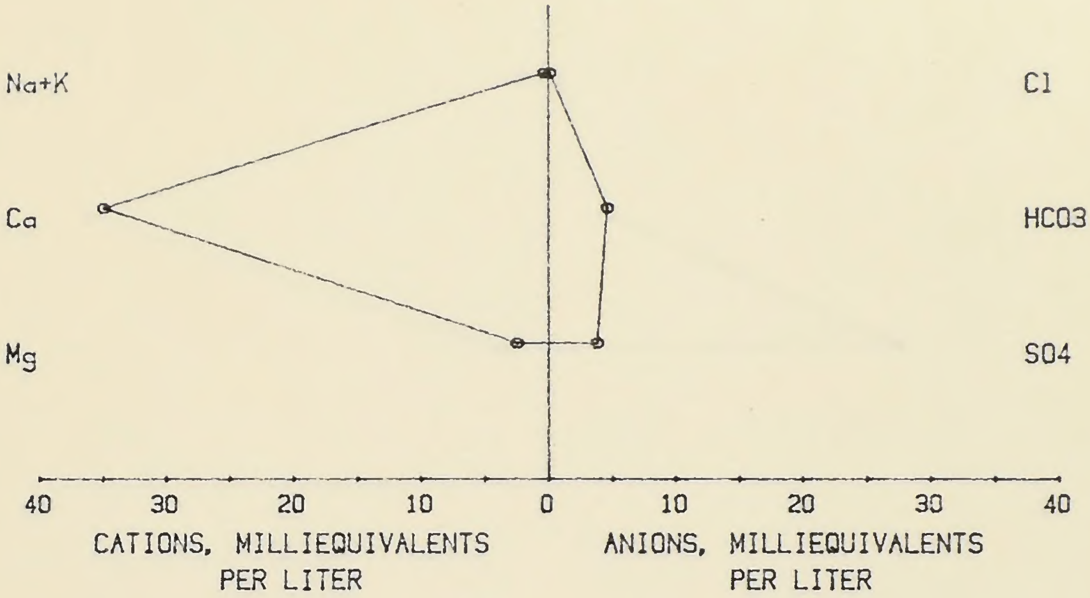

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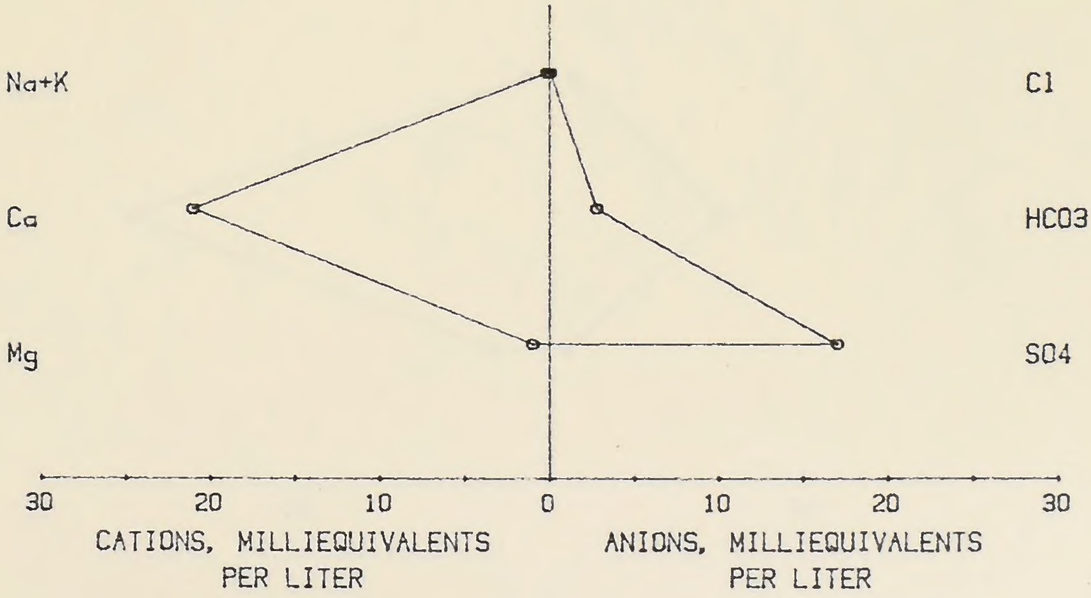

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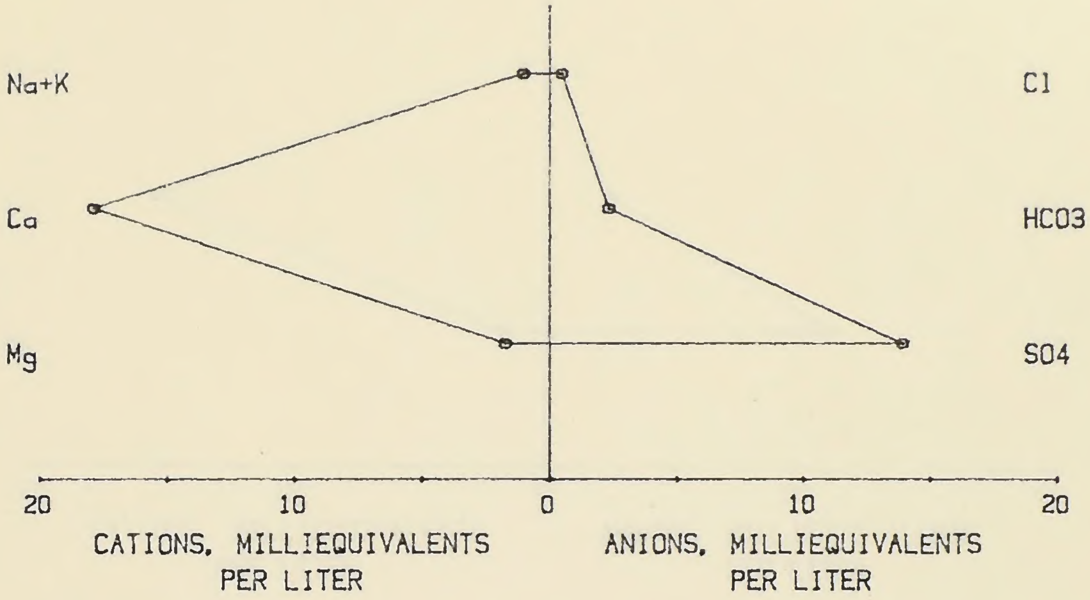

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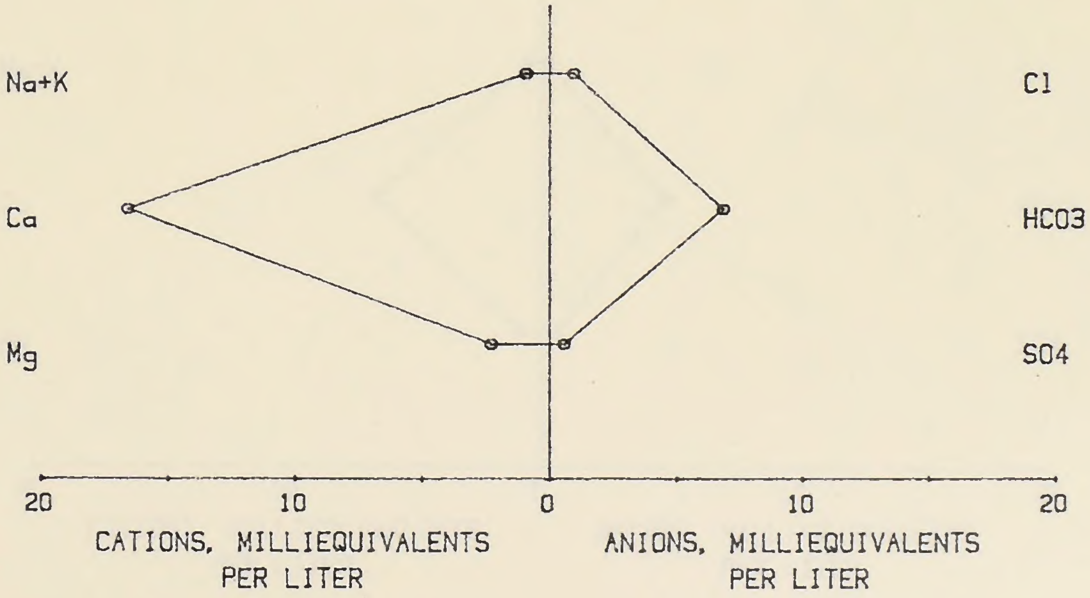

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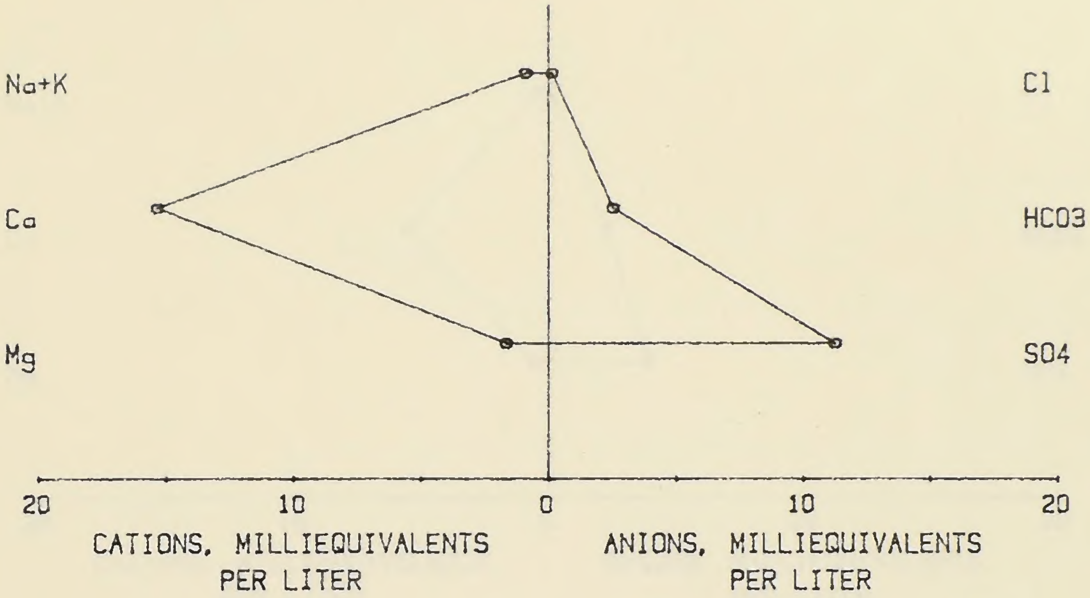

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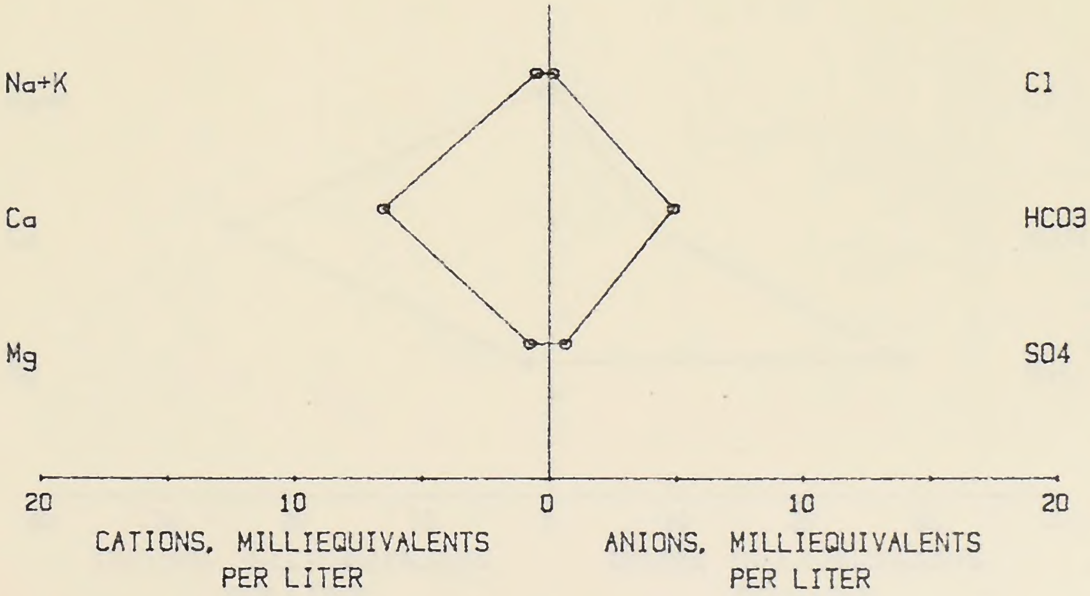

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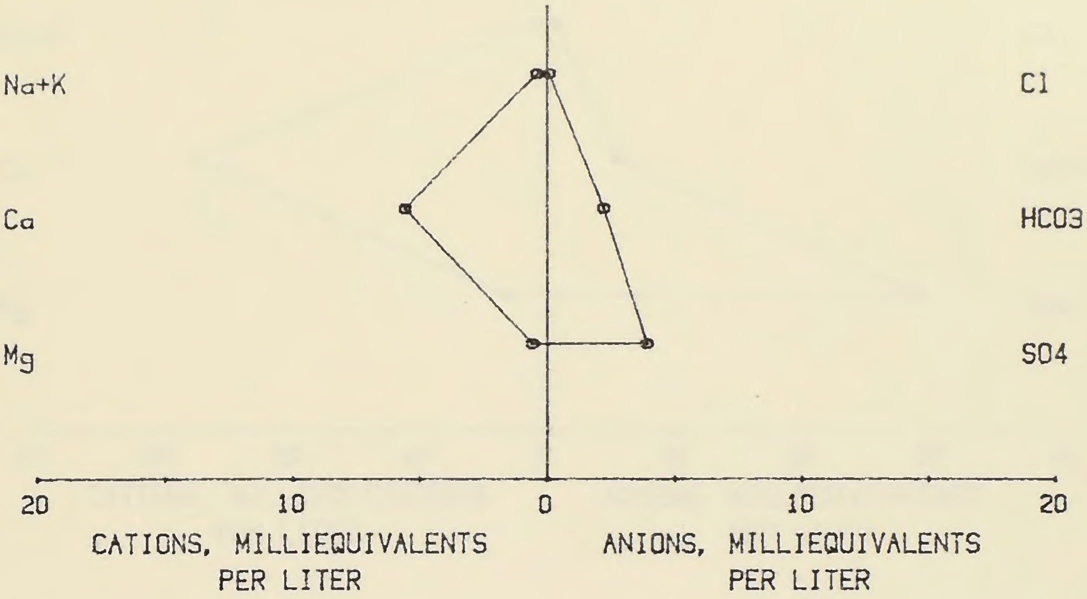

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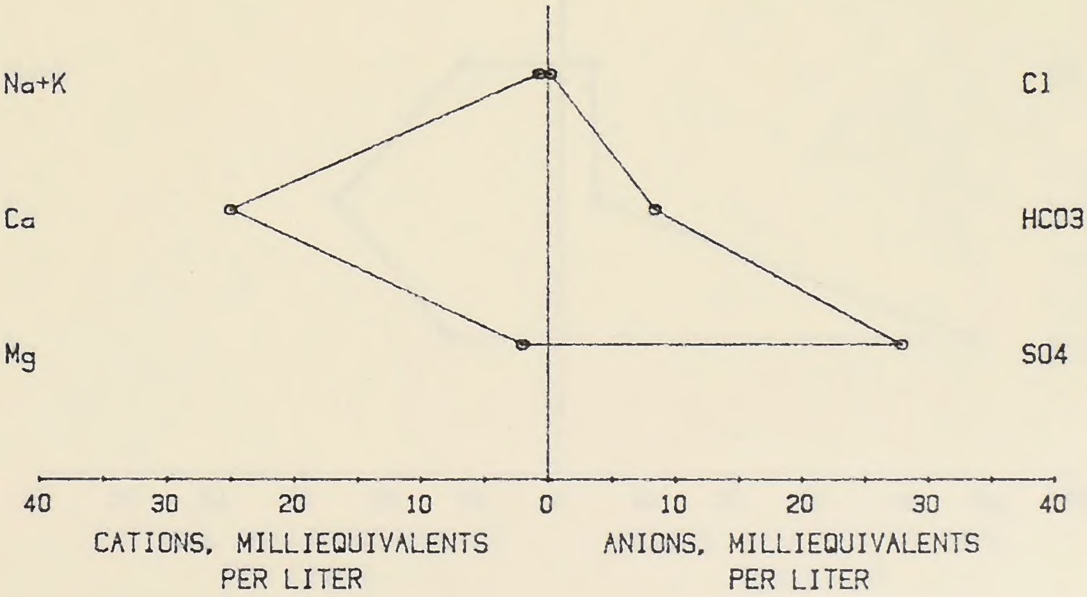

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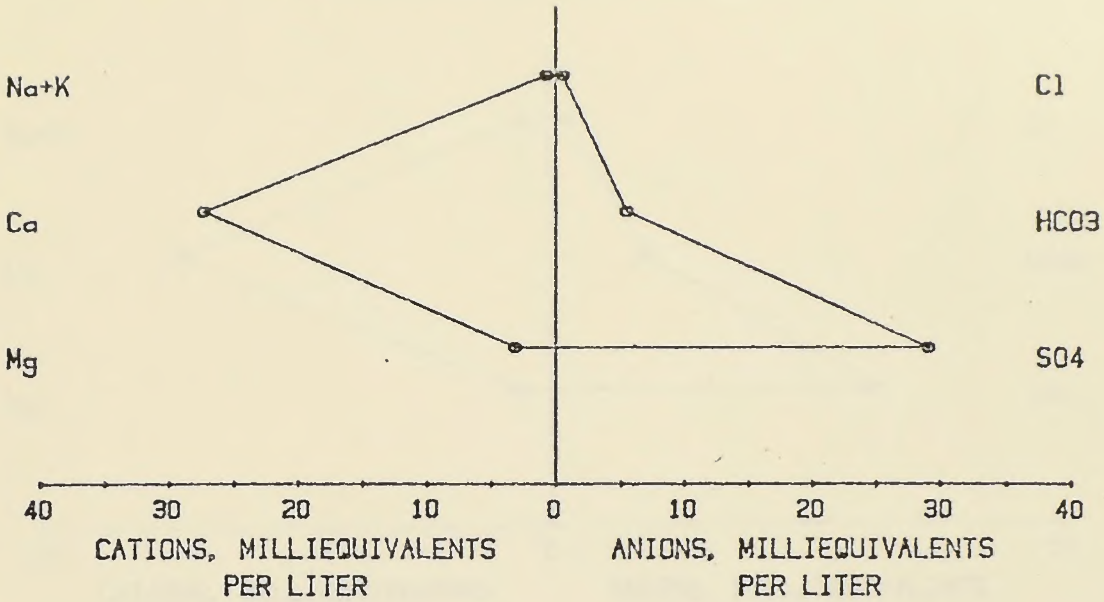
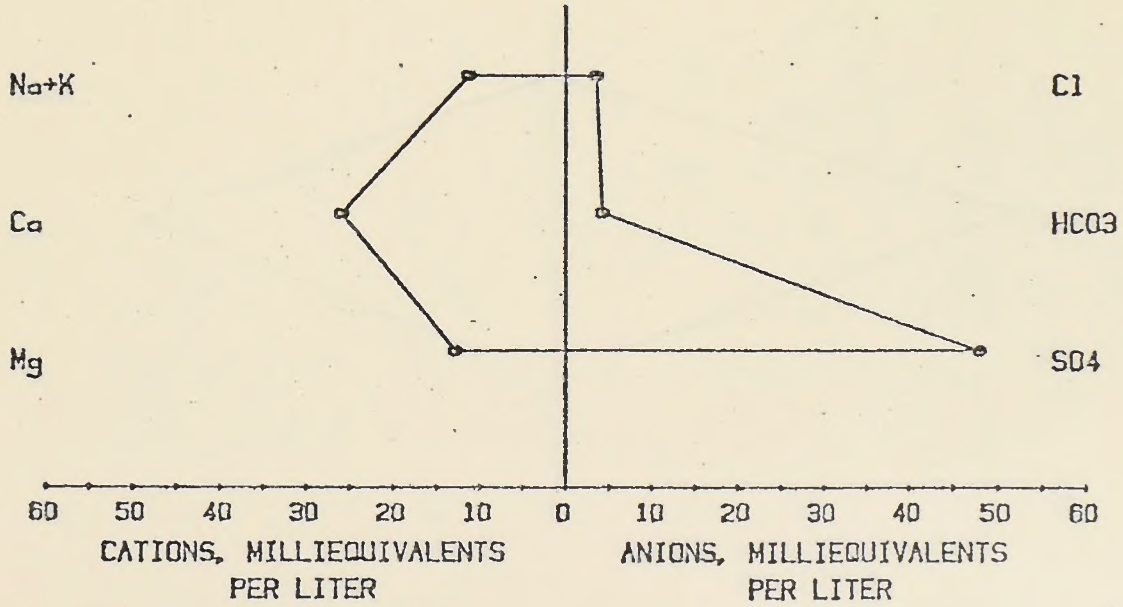


BITTER SPRING 3-23-78



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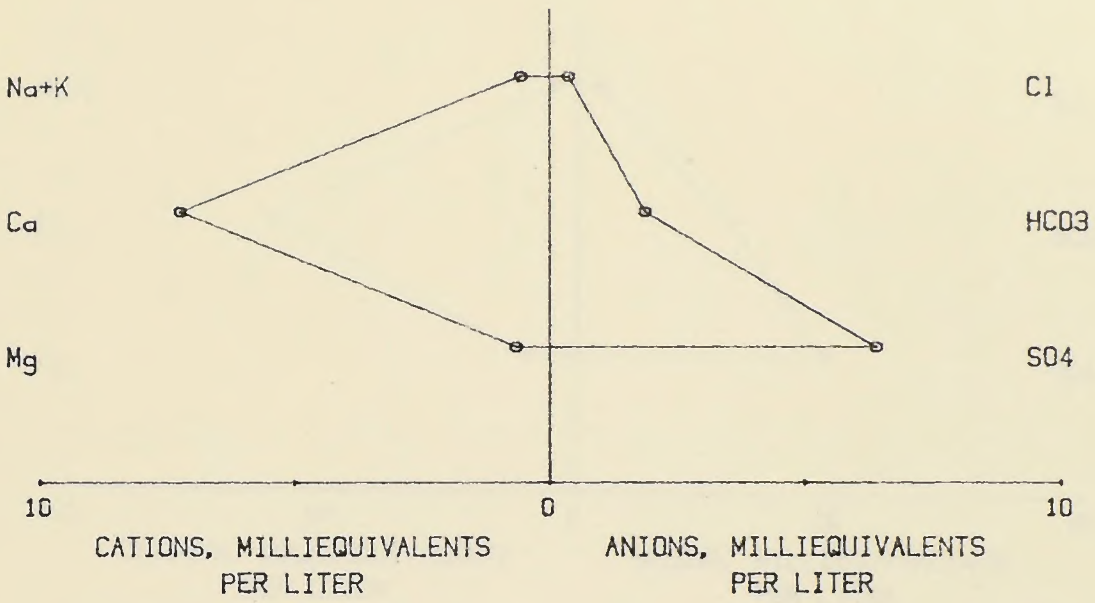

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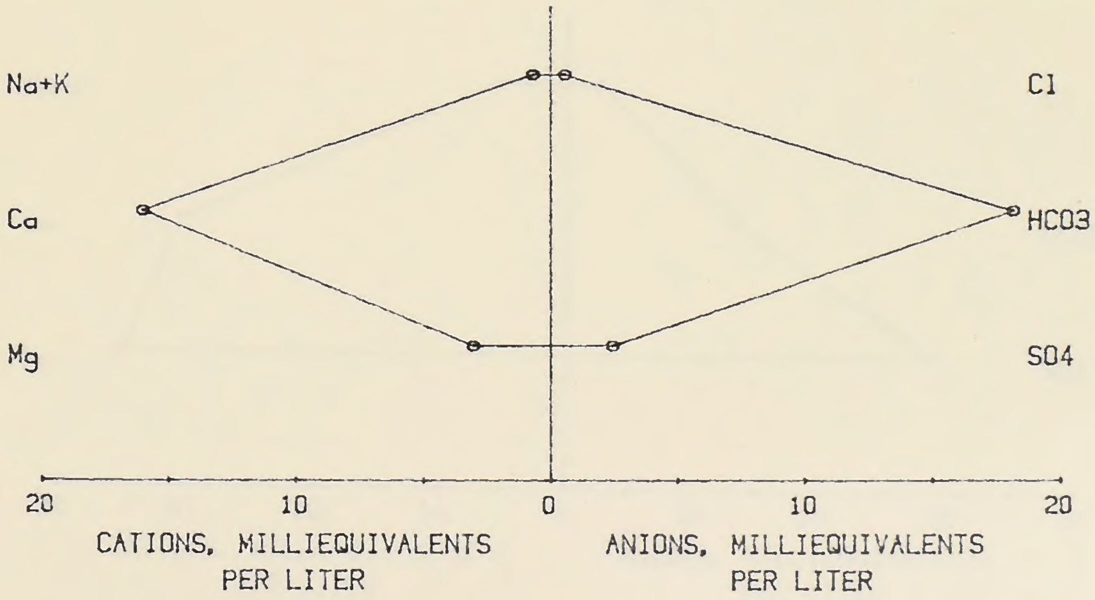

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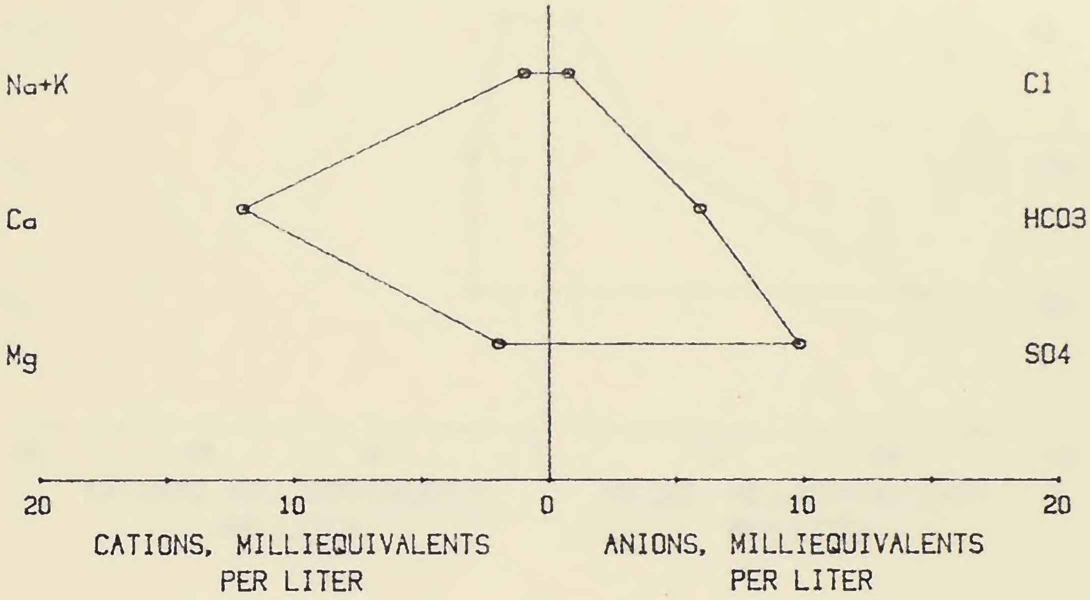

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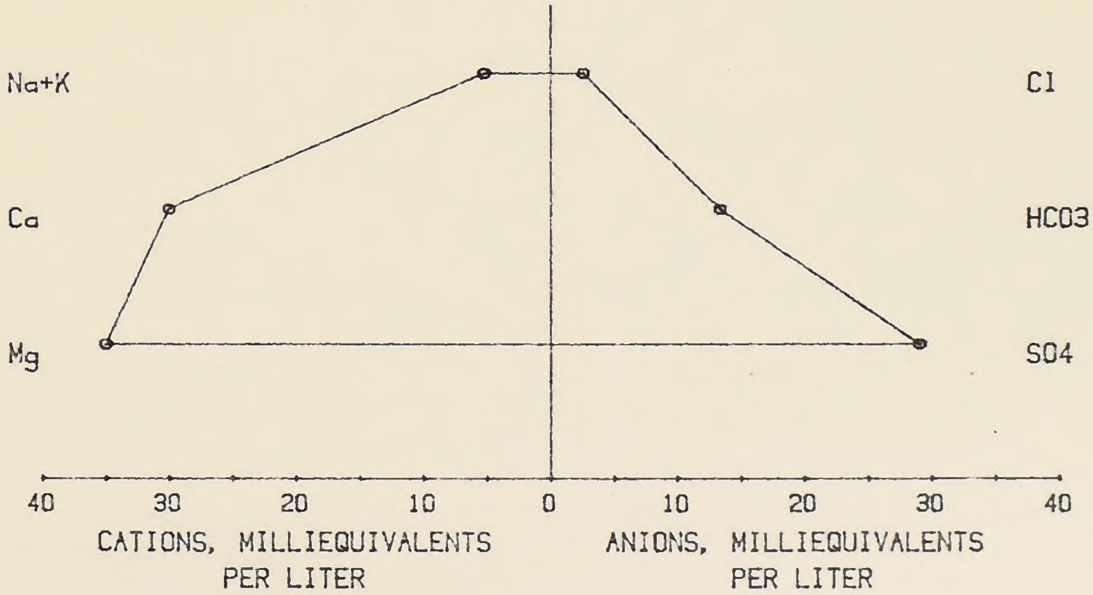

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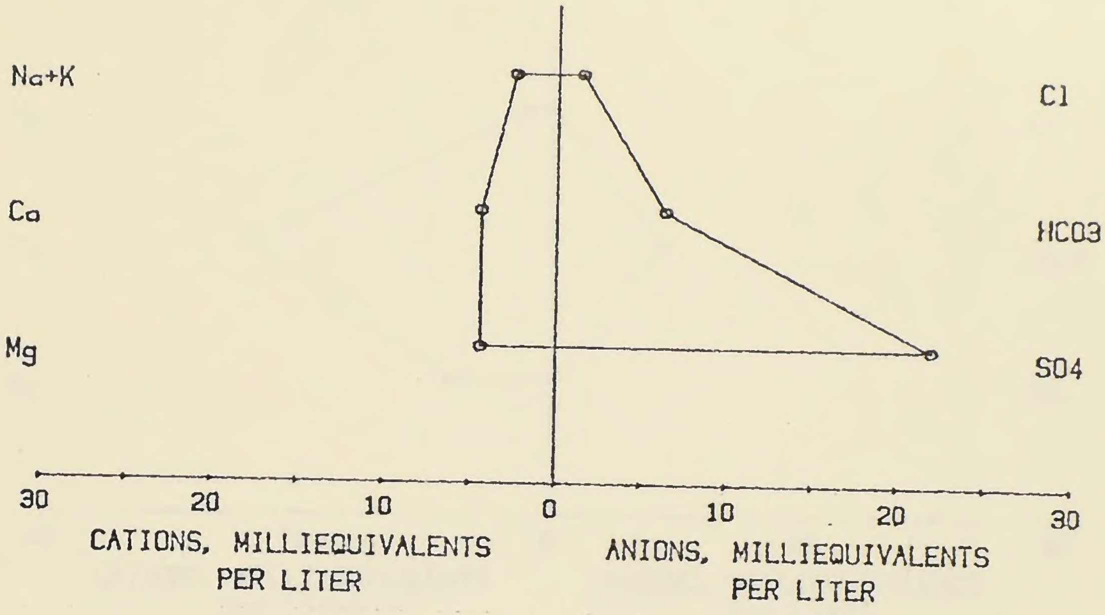

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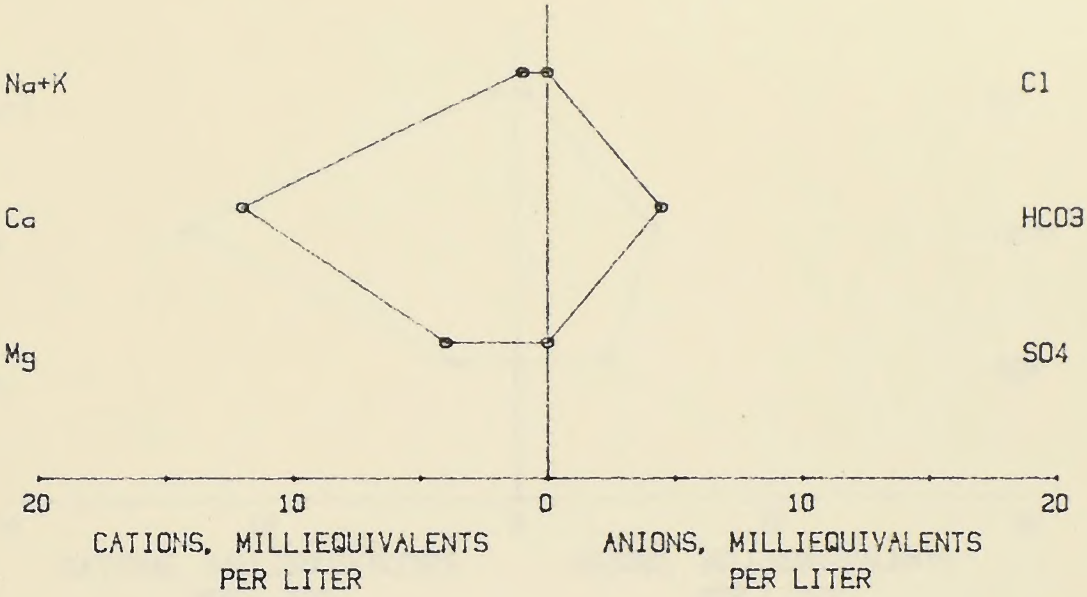

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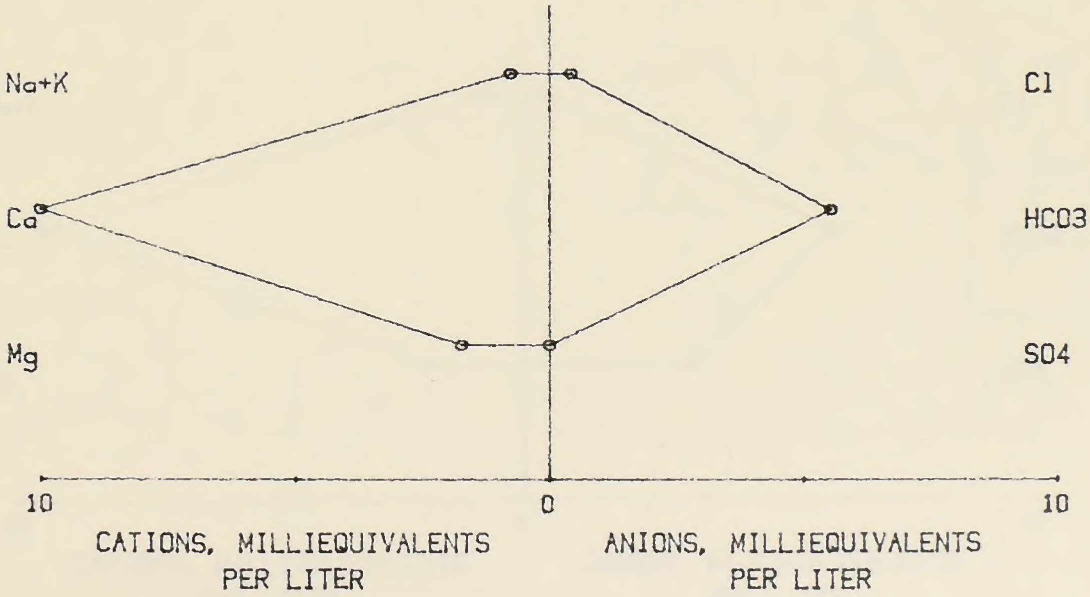

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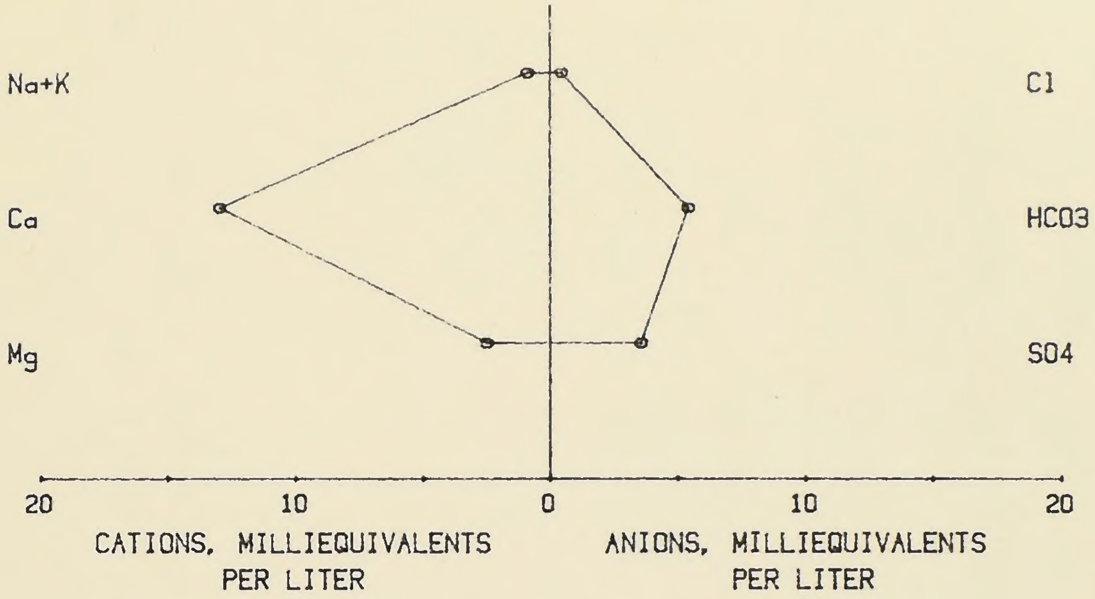

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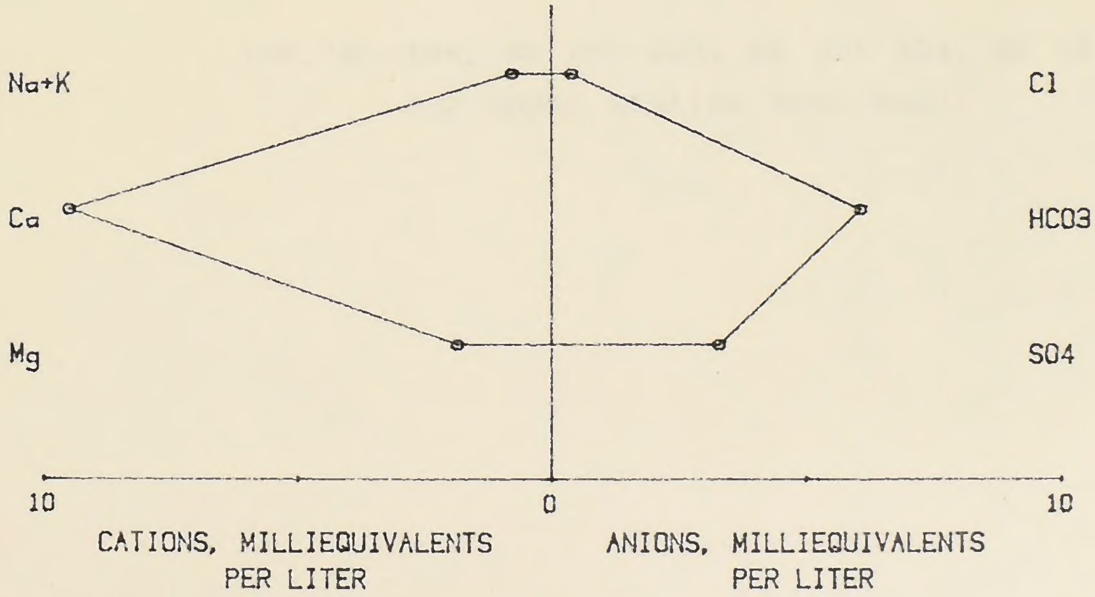
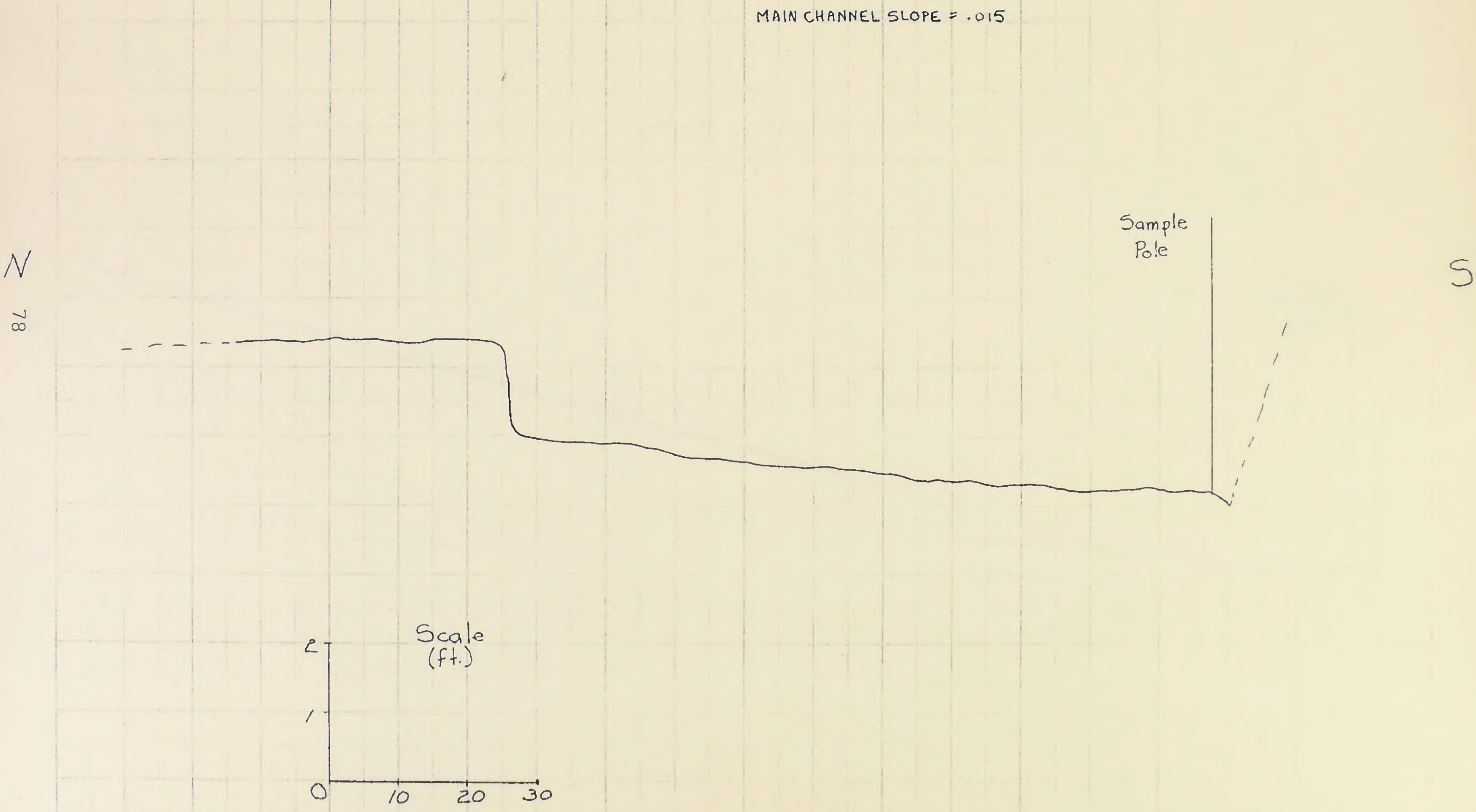


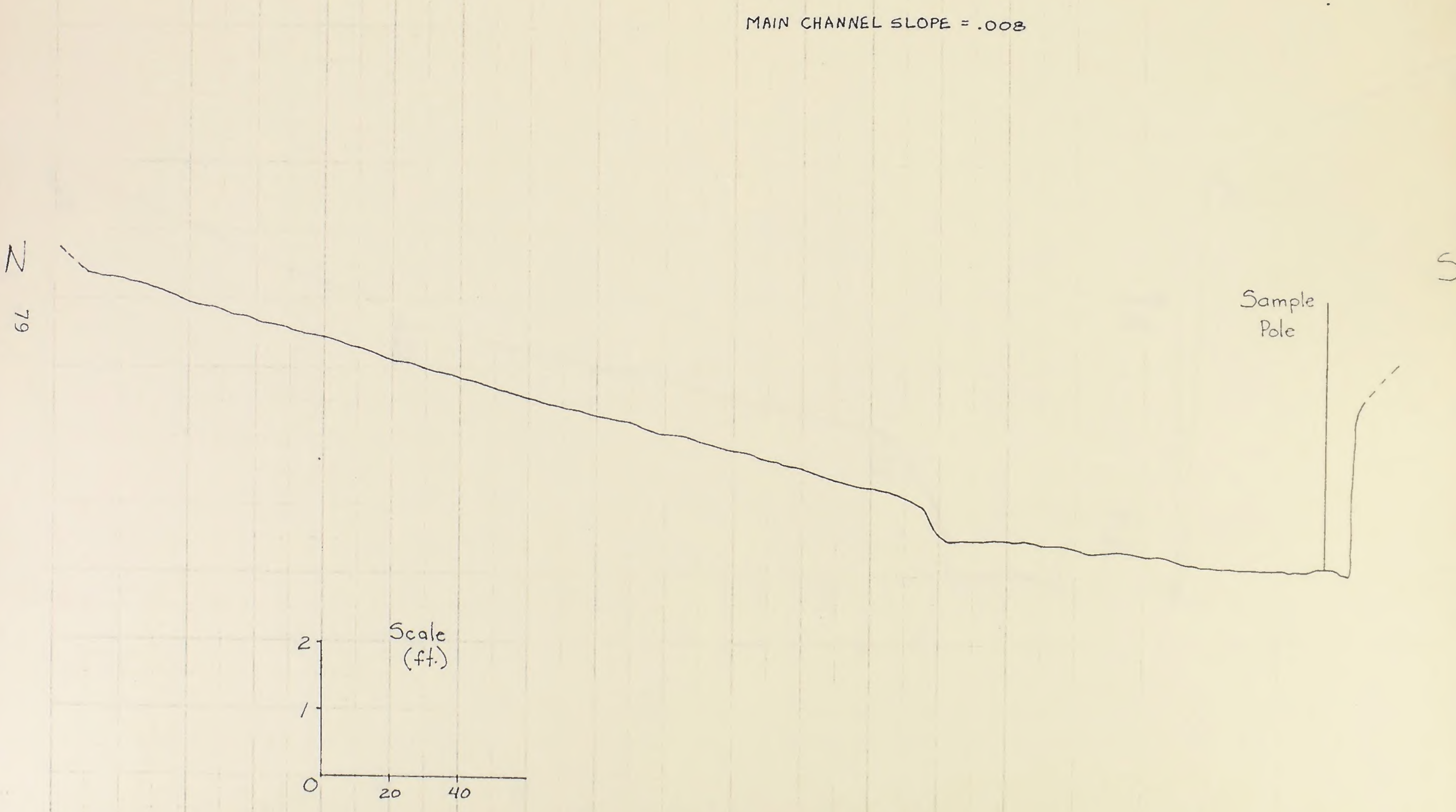
APPENDIX B

Channel Profiles at Water Quality Sampling Stations and Dust Collection Transects

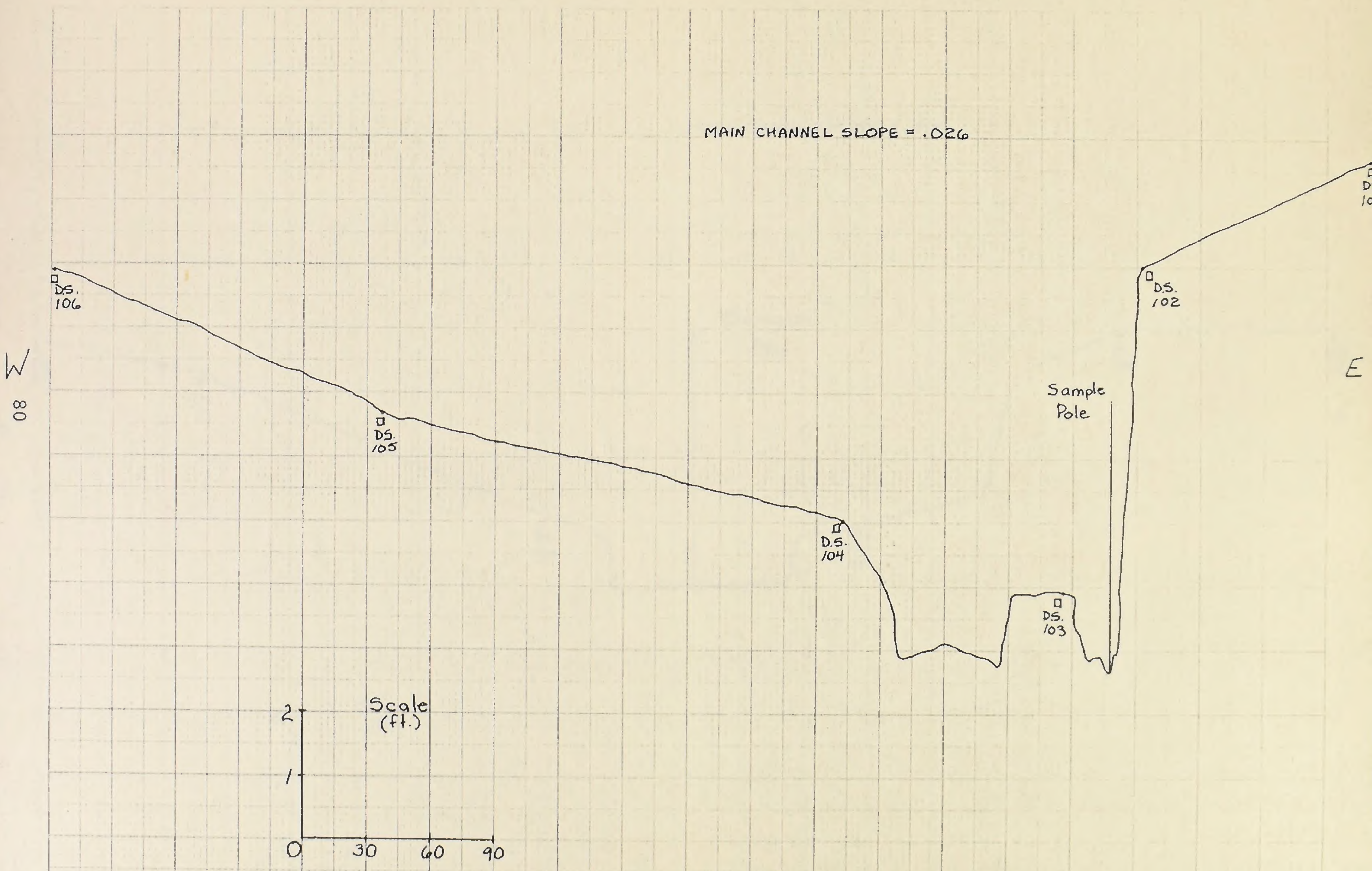
(WS 101-104, WS 201-203, WS 301-304, WS 401-402
and upper station Echo Wash)



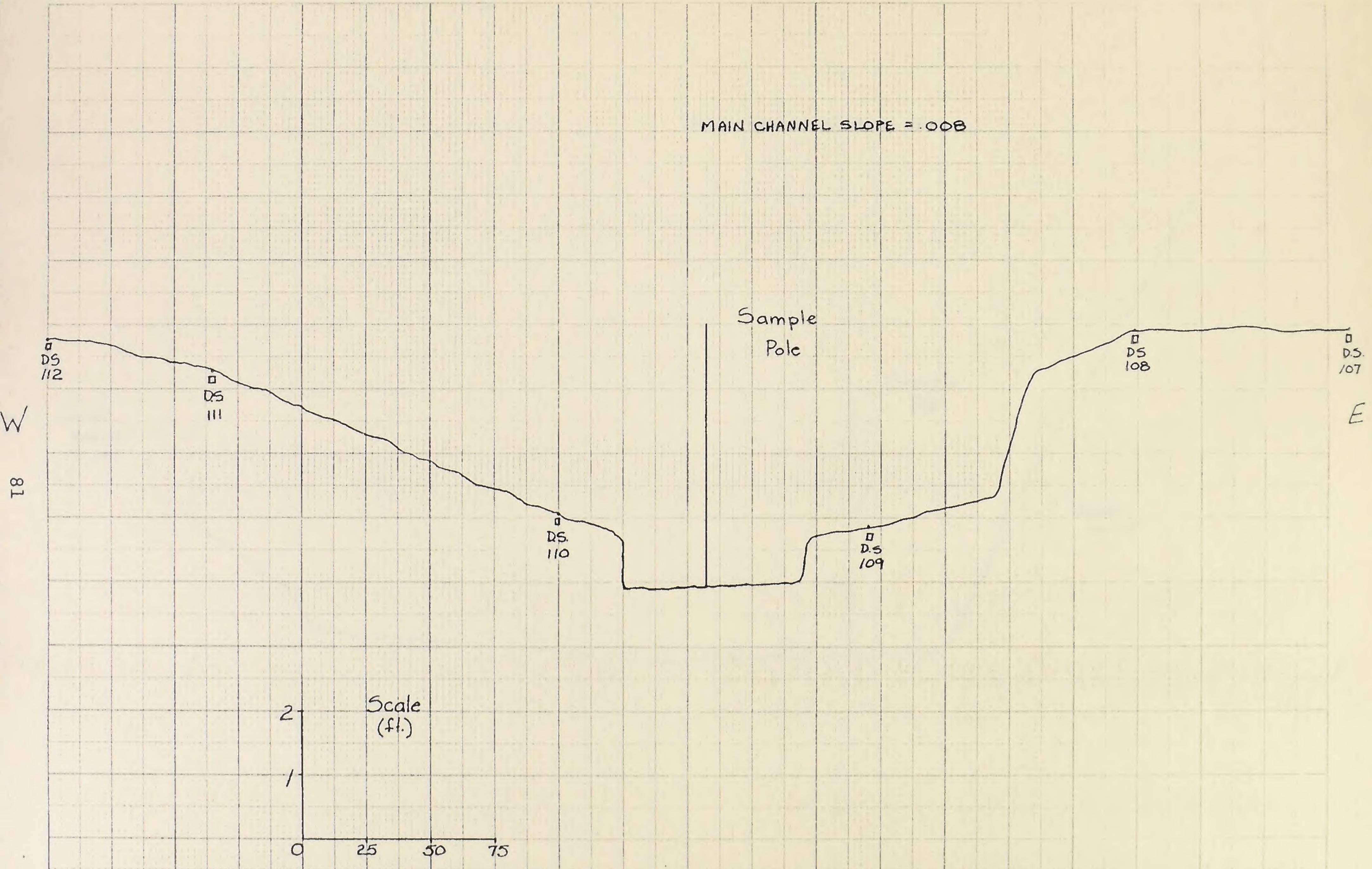
Channel Profile at WS 101



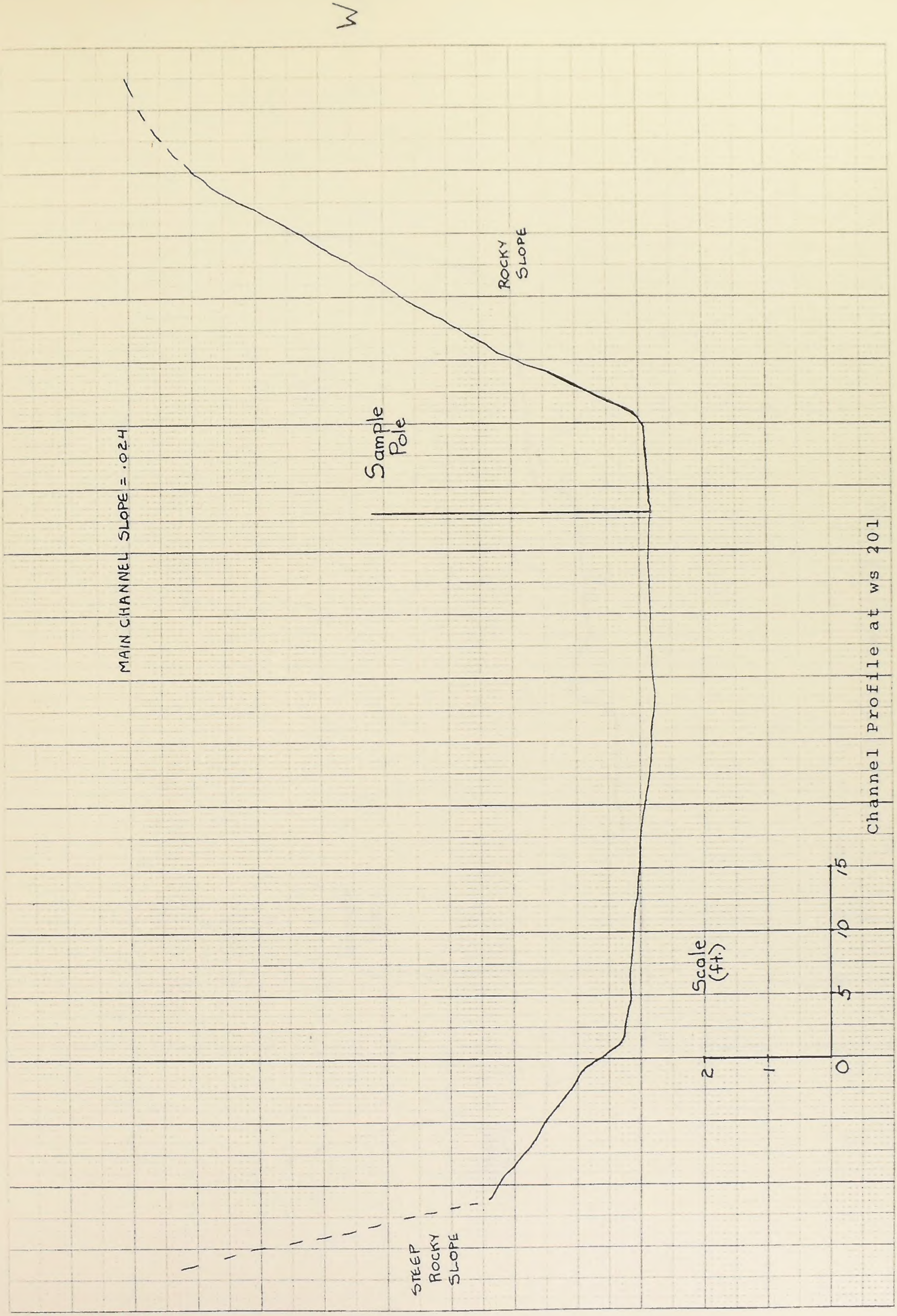
Channel Profile at WS 102



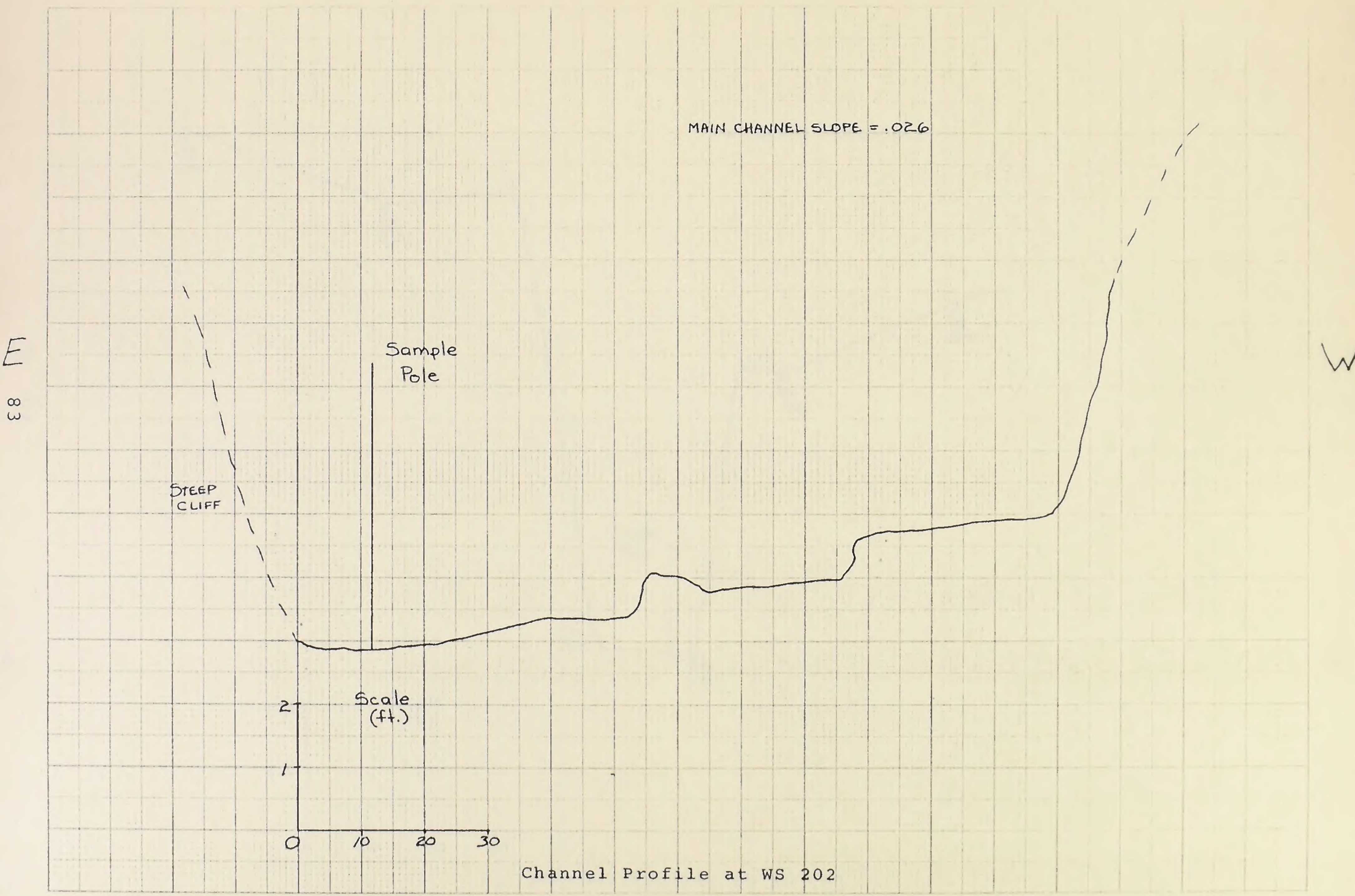
Channel Profile at WS 103



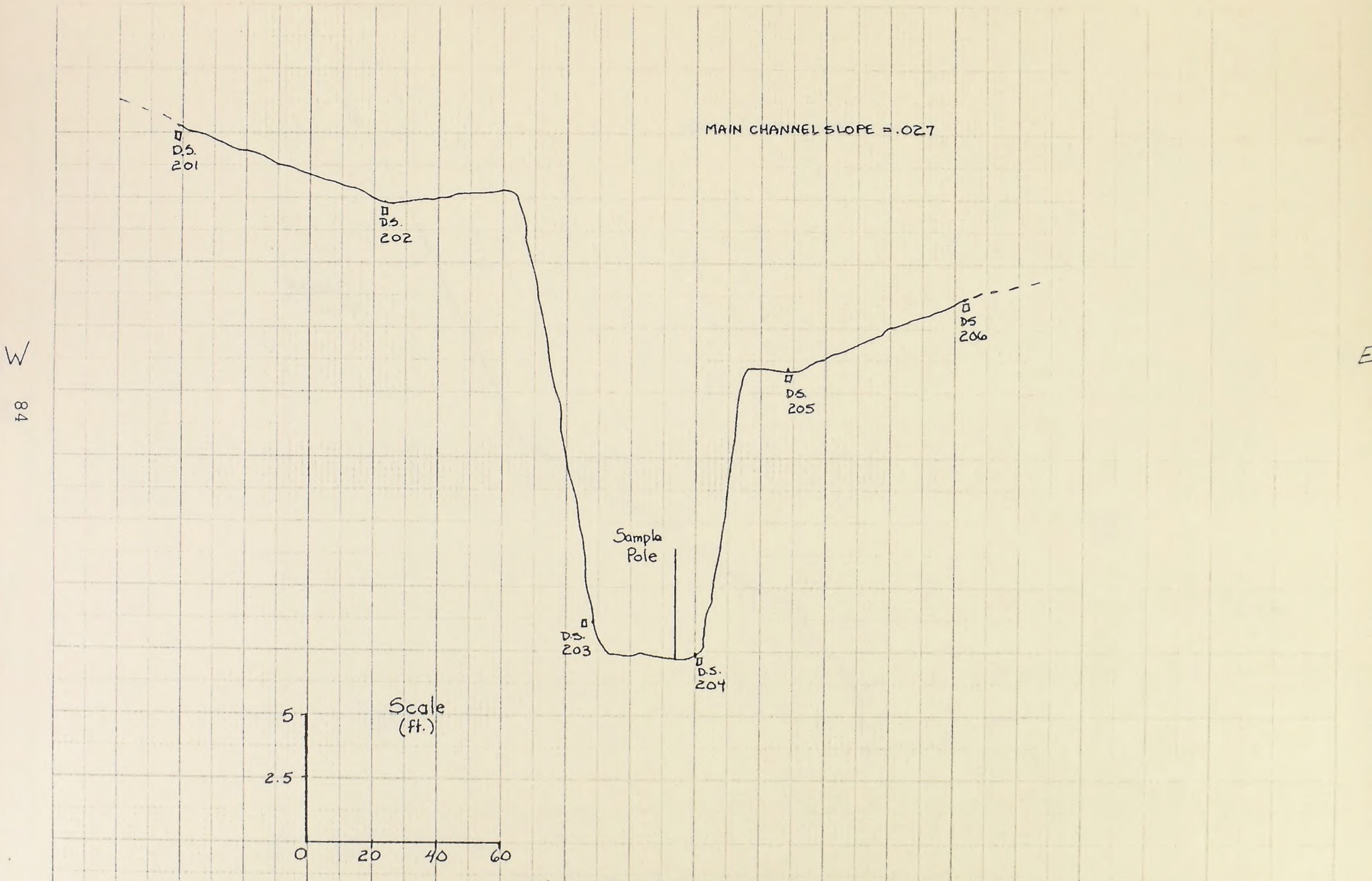
Channel Profile at WS 104



Channel Profile at ws 201



Channel Profile at WS 202



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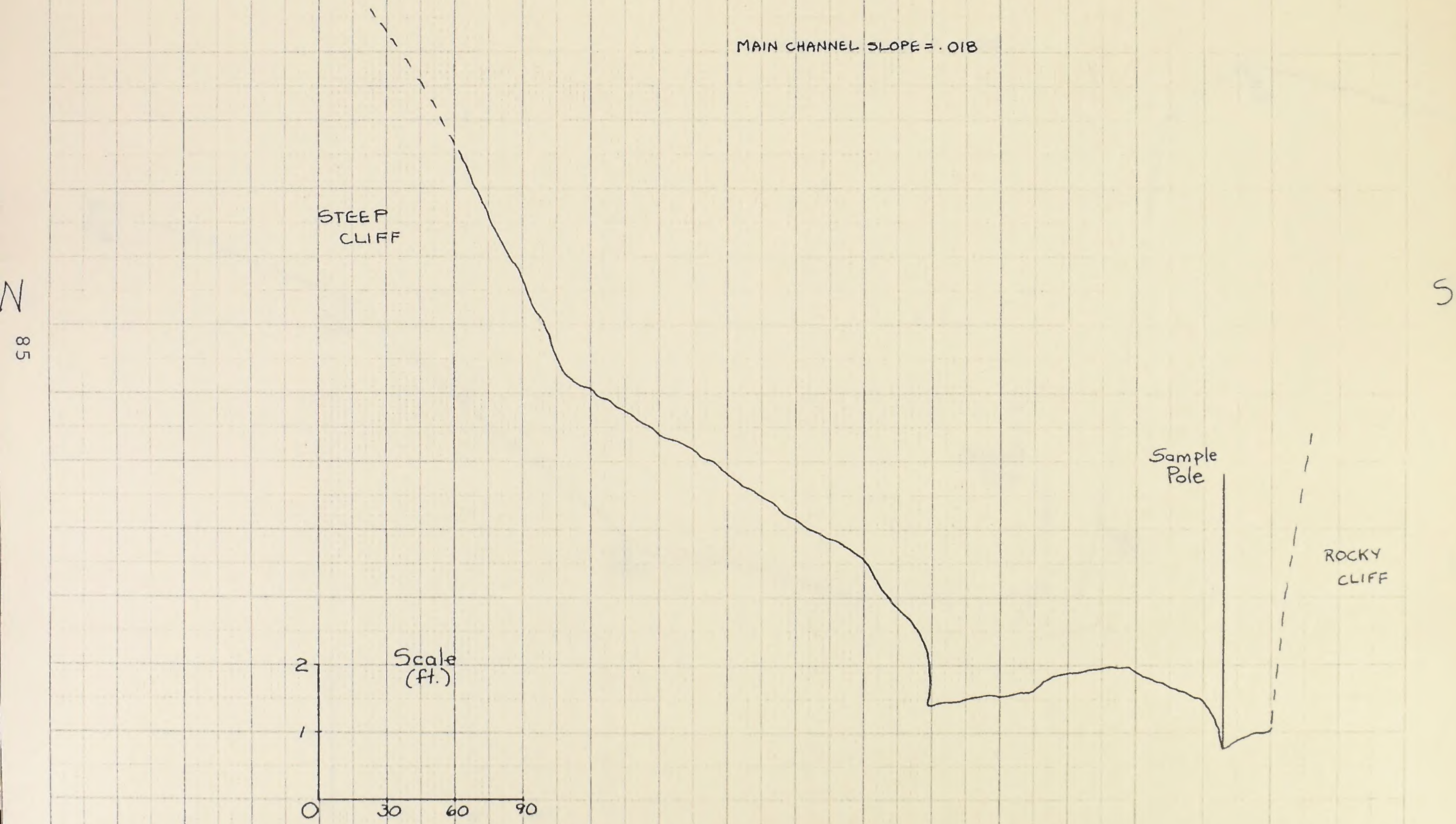
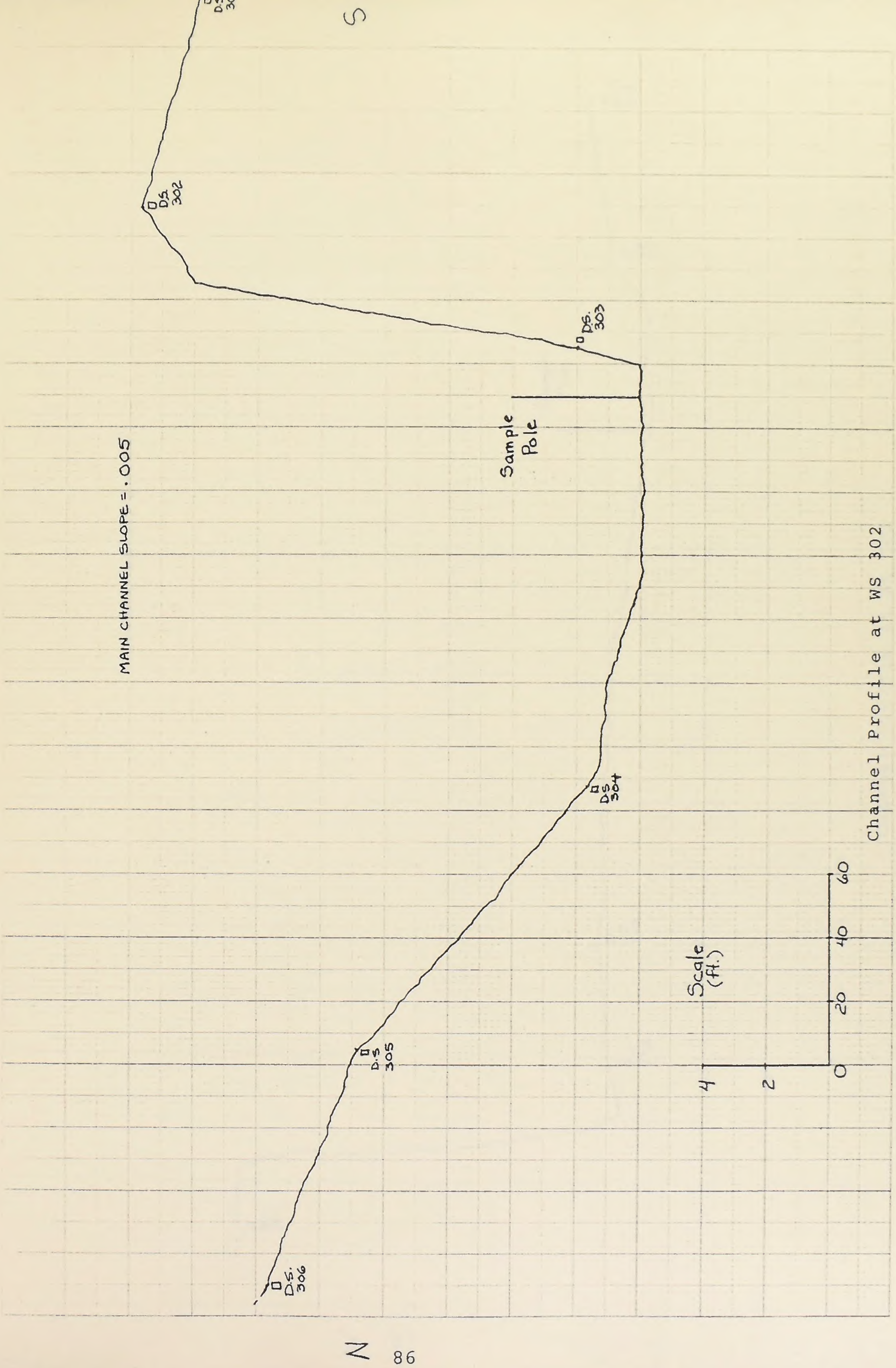
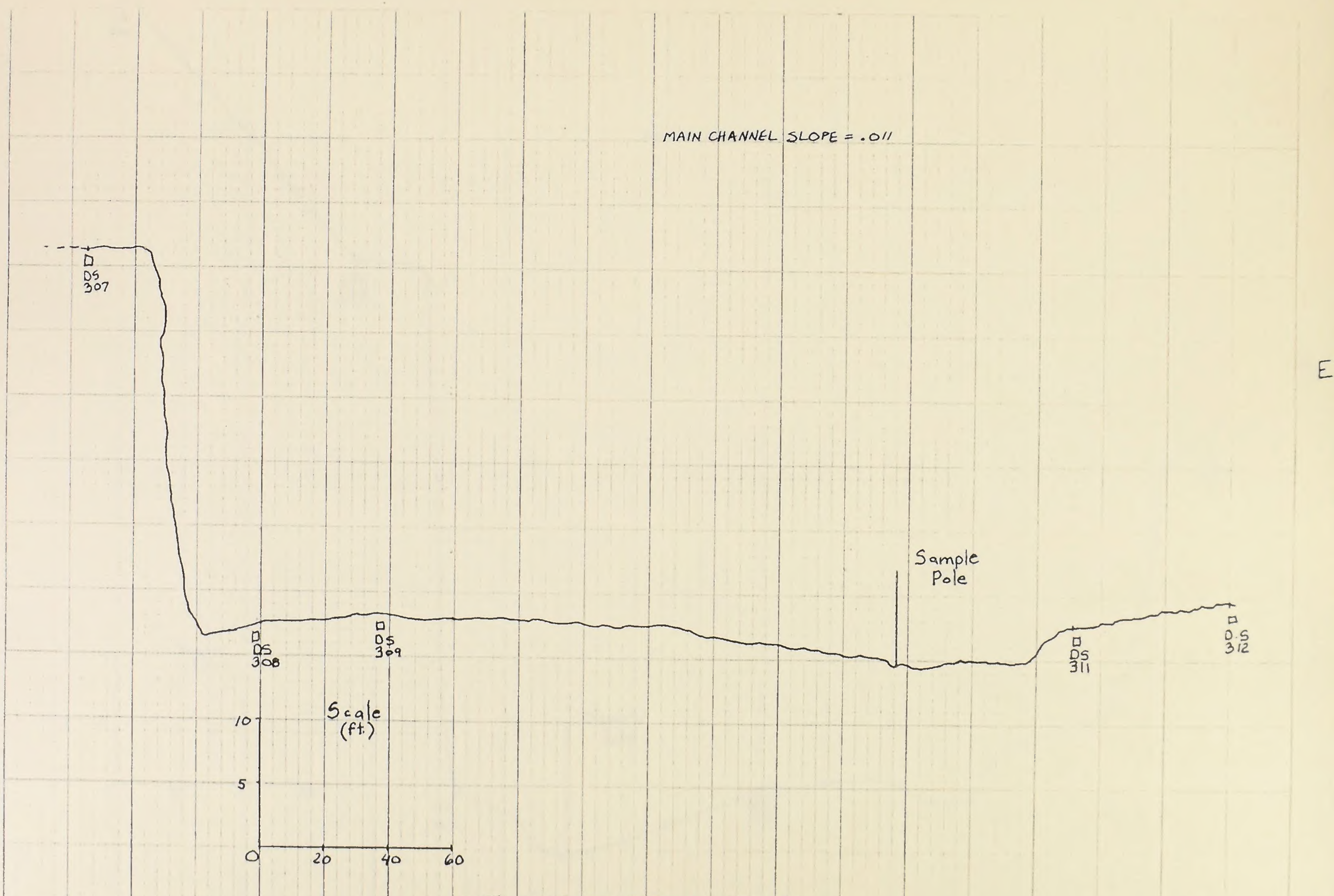


Channel Profile at WS 301



Channel Profile at WS 302



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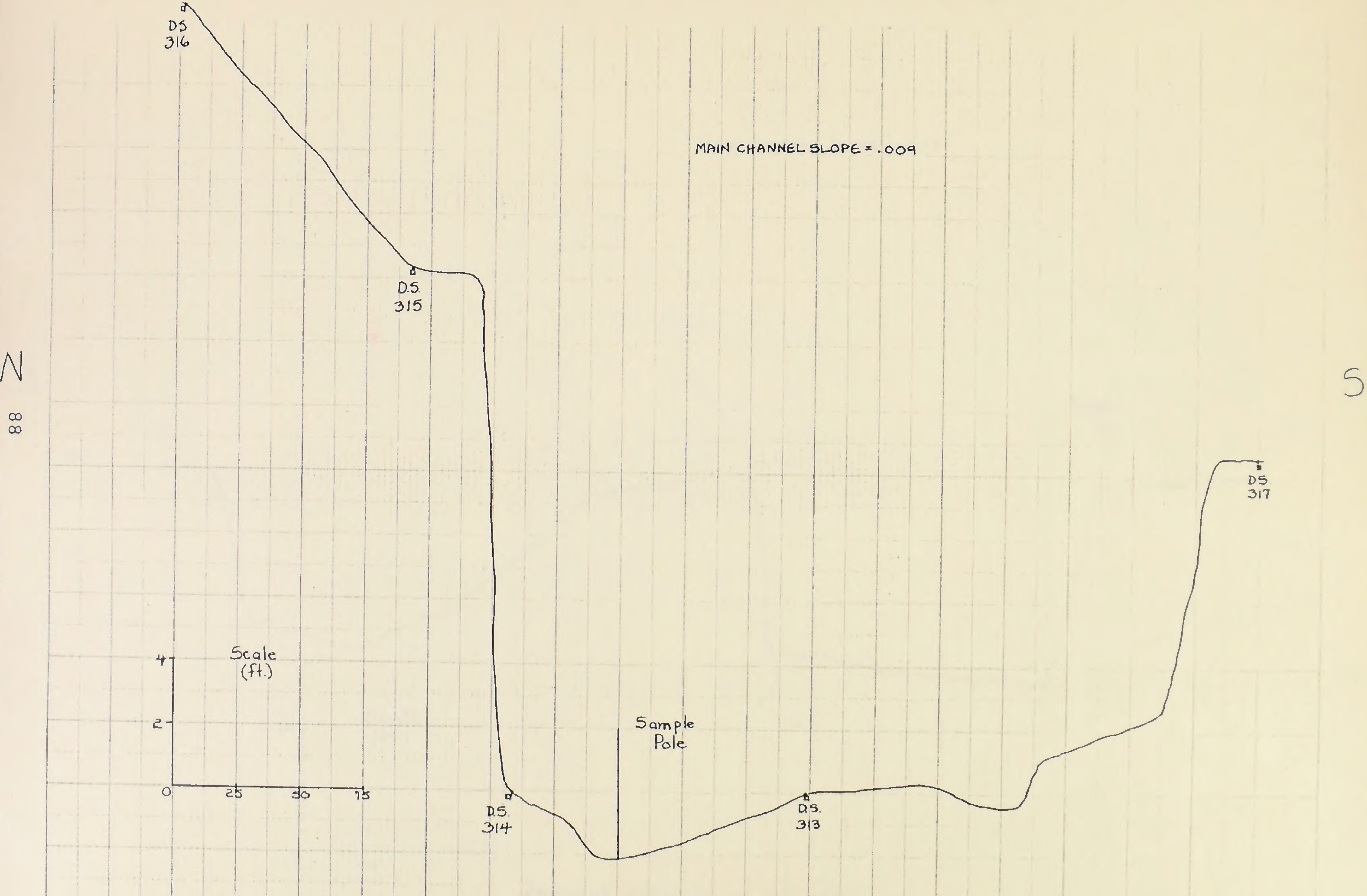
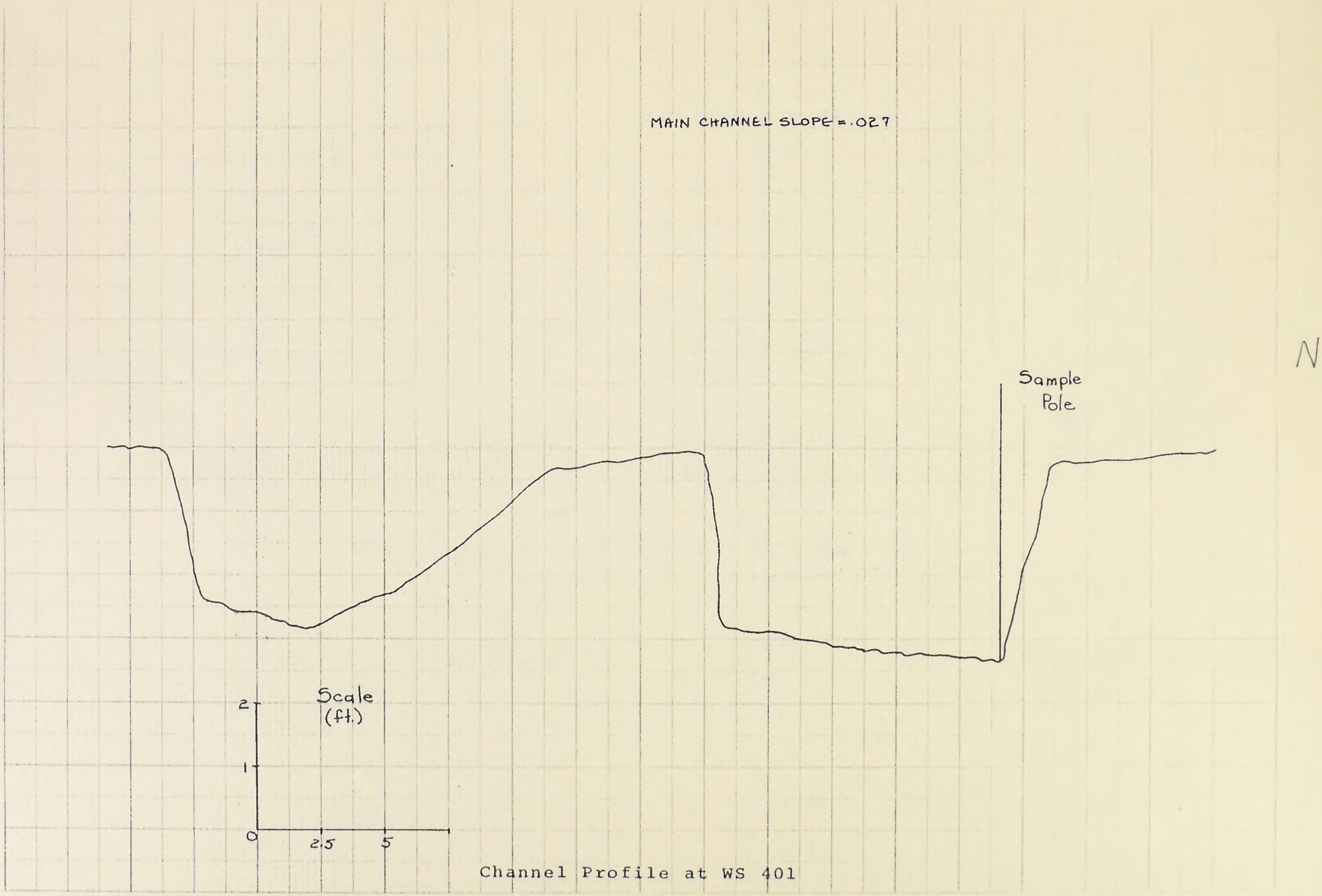
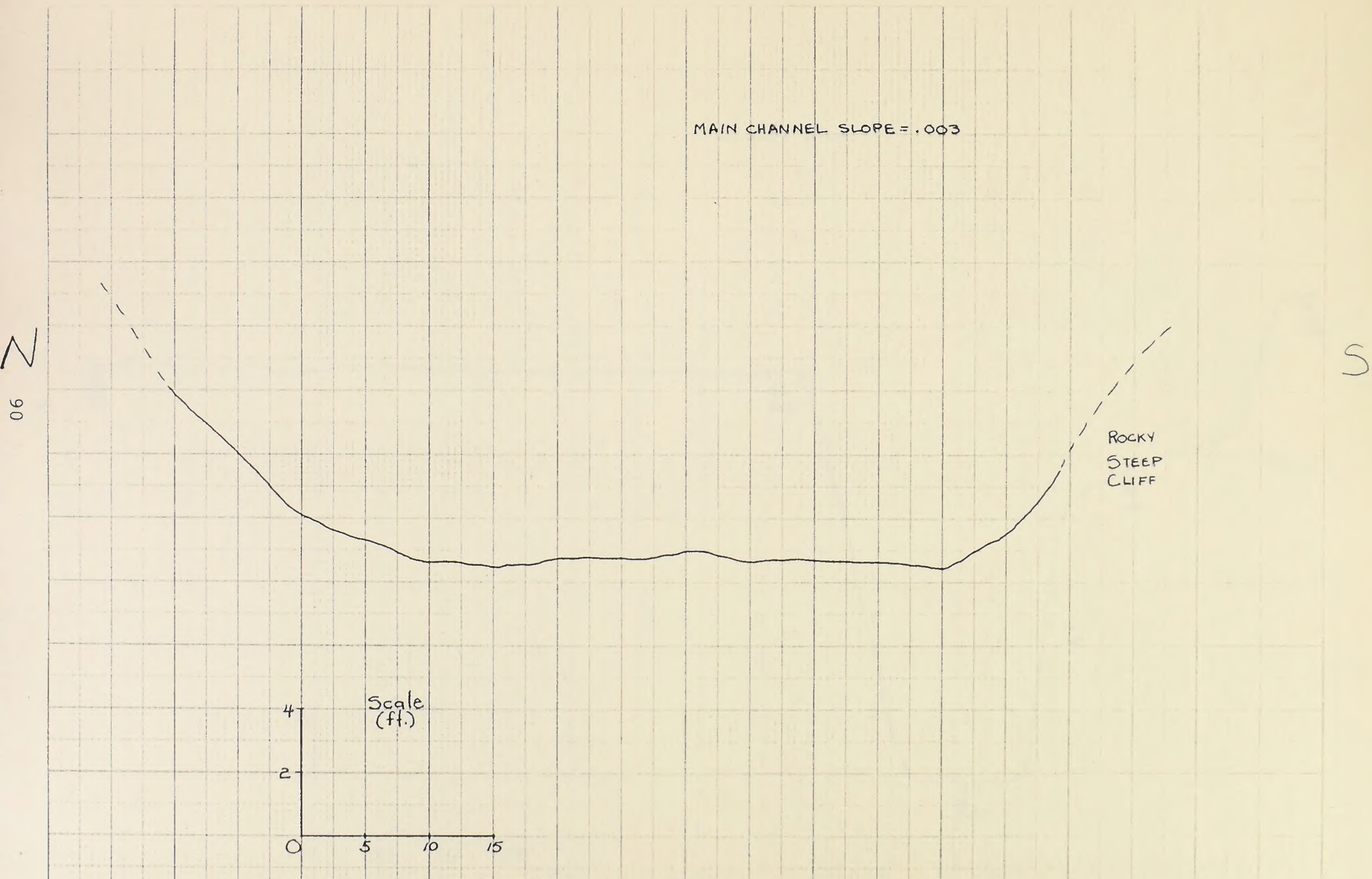


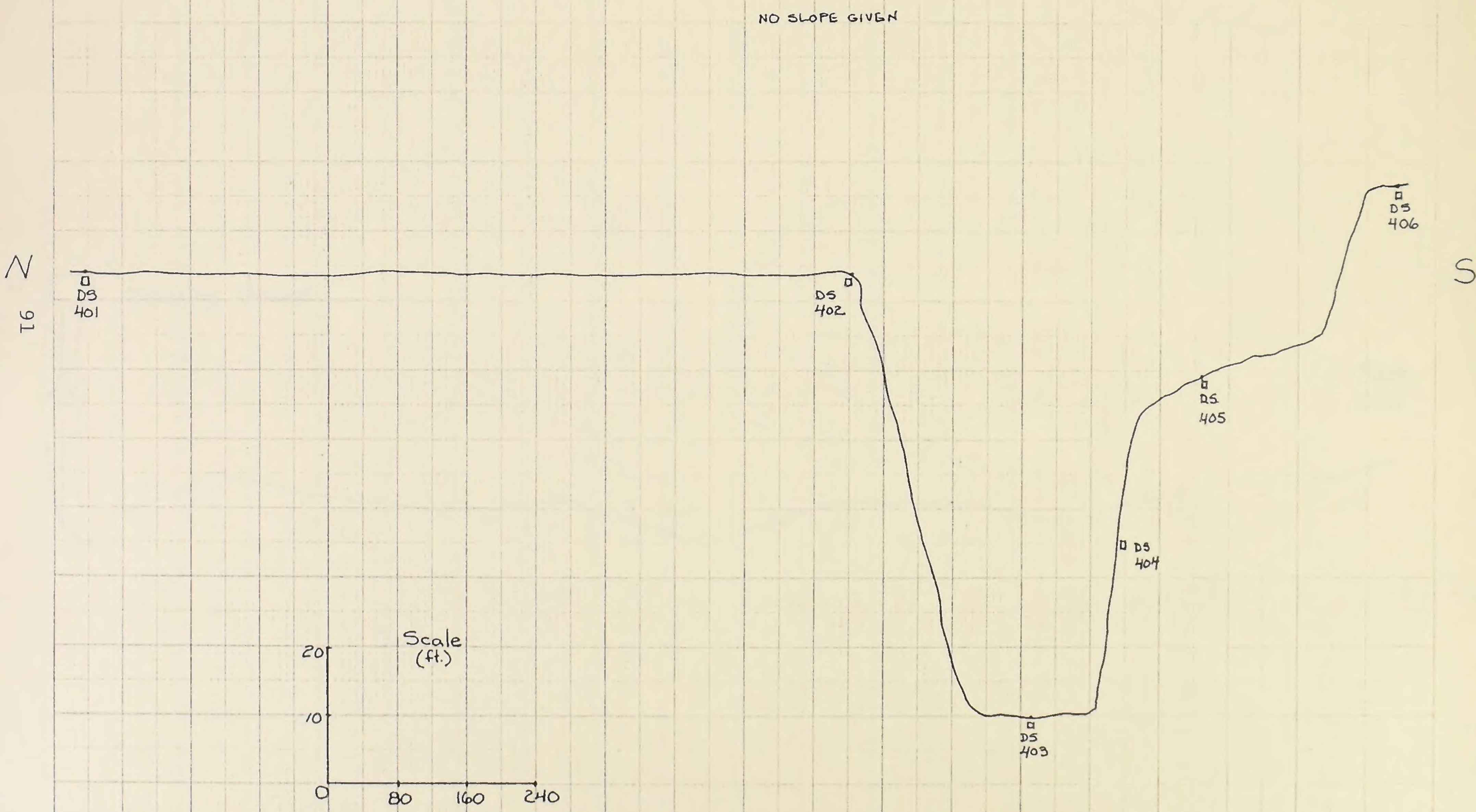
Channel Profile at WS 304



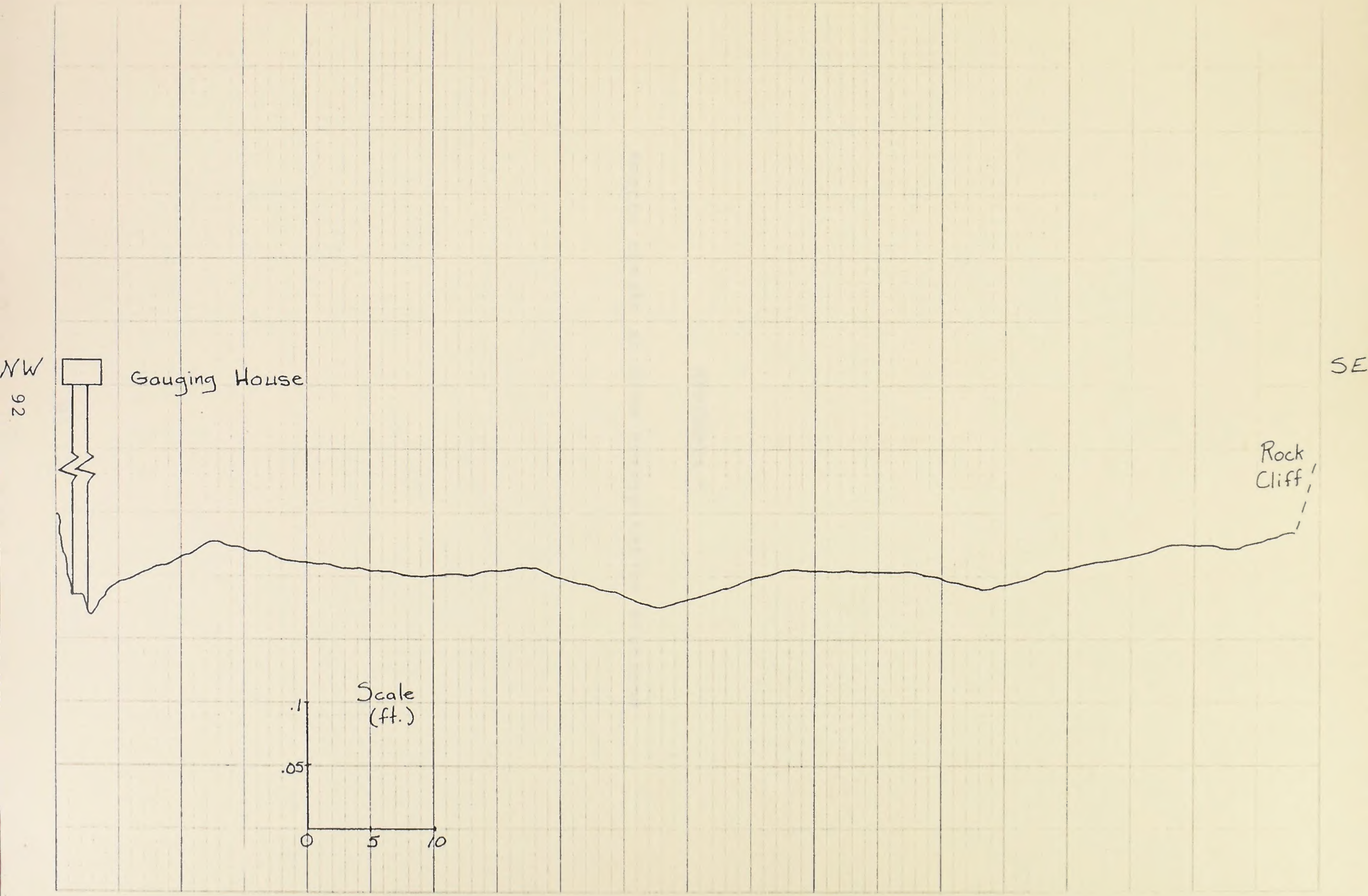
Channel Profile at WS 401



Channel Profile at WS 402



Channel Profile at Dust Sample Transect North of WS 402



Channel X-section Upper Station Echo Wash

APPENDIX C

Yearly totals at Nine Precipitation Stations

TABLE C-1: Precipitation Data for Study Basin Area, North Shore of Lake Mead, NV

	Annual Precipitation		
Station	in. (cm) 1977	in. (cm) 1978	in. (cm) 1979
Las Vegas	3.97 (10.8)	7.65 (19.4)	6.52 (16.6)
Sunrise Manor	3.77 (9.6)	7.64 (19.4)	6.53 (16.6)
Boulder Beach	3.59 (9.1)	10.34 (22.3)	3.67 (9.3)
Las Vegas Wash	3.44 (8.7)	8.18 (20.8)	5.41 (13.7)
Callville Bay	3.61 (9.2)	11.52 (29.3)	4.52 (11.5)
Echo Bay	3.37 (8.6)	10.09 (25.6)	5.03 (12.8)
Overton Beach	1.53 (3.4)	3.54* (9.0)	6.01 (15.3)
Temple Bar	5.64 (14.3)	7.45 (18.9)	5.92 (15.0)
Valley of Fire	4.72 (12.0)	16.90 (42.9)	12.50 (31.6)

*incomplete record

APPENDIX D

SOILS DATA

Information was supplied by Philip Alard and Claudia Carlton of the Las Vegas District Office of the BLM, March 7, 1980.

Basin: Government Wash

Soil Map Unit (Map Unit #): Canutio-Aztec-Arizo Families
Association (3020)

Percent of Basin: 60+

Description of Major Soils (Percent of Mapping Unit):

1. Canutio Family (40) gravelly fine sandy loam, 2 to 8 percent slopes; (loamy skeletal, mixed (calcareous) thermic, typic torriorthents)
2. Aztec Family (30) very gravelly, fine sandy loam, 2 to 8% slopes; (loamy-skeletal, mixed, thermic, cambic gypsionthids).
3. Arizo Family (15) very gravelly loamy sand, 2 to 8% slopes; (sandy skeletal, mixed, thermic, typic torriorthents).

Basin: Government Wash

Soil Map Unit (Map Unit #): Akela-Rock Outcrop - courthouse families association (3002)

Percent of Basin: 10

Description of Major Soils (Percent of Mapping Unit):

1. Akela Family (30) stony sandy loam, 15 to 50% slopes (loamy-skeletal, mixed (calareous) thermic, lithic torriorthents)
2. Rock Outcrop (30) Mixed Rocks: limestone, sandstone, volcanics
3. Courthouse Family (30) very gravelly sandy loam, 15 to 50% slopes (loamy, mixed (calcaleous) mesic, lithic torriorthents)

Basin: West End Wash

Soil Map Unit (Map Unit #): Akela Family - Rock Outcrop - Nickel Family Association (3003)

Percent of Basin: 60+

Description of Major Soils (Percent of Mapping Unit):

1. Akela Family (50) extremely stony sandy loam, 15 to 30% slopes, (loamy-skeletal, mixed (calcareous) thermic, lithic torriorthents)
2. Rock Outcrop (15)
3. Nickel Family (15) very gravelly sandy loam; 15 to 30% slopes (loamy-skeletal, mixed, thermic, typic calciorthids)

Basin: West End Wash

Soil Map Unit (Map Unit #): Akela-Rock Outcrop - Courthouse Families Association (3002)

Percent of Basin: 15+

Description of Major Soils (Percent of Mapping Unit):

1. See description for Government Wash

Basin: Echo Wash

Soil Map Unit (Map Unit #): Tenncee - Weiser - Normud Families
Association (3088)

Percent of Basin: 40

Description of Major Soils (Percent of Mapping Unit):

1. Tencee Family (40) extremely gravelly sandy loam 4 to 8% slopes (loamy skeletal, carbonate, thermic, shallow typic paleorthids)
2. Weiser Family (35) very gravelly sandy loam 4 to 8% slopes, (loamy-skeletal, carbonatic thermic typic (alciorthids)
3. Normid Family (20) extremely gravelly sandy loam, 2 to 4% slopes (sandy-skeletal, carbonatic, thermic typic torriorthents).

Basin: Echo Wash

Soil Map Unit (Map Unit #): Typic Torriorthents, Shallow-Elvada-Yessum Family Association (3046)

Percent of Basin: 20

Description of Major Soils (Percent of Mapping Unit):

1. Typic torriorthents, shallow (45) 0 to 4% slopes, (loamy, gypsic, thermic, shallow typic torriorthents)
2. Elvada Family (25) sandy loam moderately deep, 2 to 8% slopes, (coarse-loamy, gypsic, thermic, typic torriorthents)
3, Yessum Family (20) sand loam, 2 to 15% slopes (coarse-loamy, gypsic, thermic typic gypsiorthids)

Basin: Echo Wash

Soil Map Unit (Map Unit #): Weiser - Isom Families - Rock Outcrop Association (3097)

Percent of Basin: 10

Description of Major Soils (Percent of Mapping Unit):

1. Weiser Family (40) very gravelly loam, 8 to 30% slope, (loamy-skeletal, carbonatic, thermic, typic Calciorthids).
2. Isom Family (35) stony sandy loam 8 to 30% slope (loamy-skeletal, carbonatic, thermic, typic torriorthents)
3. Rock outcrop (15) limestone

Basin: Echo Wash

Soil Map Unit (Map Unit #): Weiser - Cave - Arizo Families Association (3095)

Percent of Basin: 5

Description of Major Soils (Percent of Mapping Unit):

1. Weiser Family (40) very gravelly loam 15 to 30% slopes (loamy-skeletal, carbonatic, thermic typic calciorthids)
2. Cave Family (30) extremely gravelly loam, 2 to 4% slopes (loamy, mixed, thermic, shallow typic paleorthids)
3. Arizo Family (15) very gravelly loam 0 to 2% slopes (sandy-skeletal, mixed, thermic typic torriorthents)

Basin: Valley of Fire Wash

Soil Map Unit (Map Unit #): Tencee-Weiser-Normud Families Association (3088)

Percent of Basin: 40

Description of Major Soils (Percent of Mapping Unit):

1. See description for Echo Wash

Basin: Valley of Fire Wash

Soil Map Unit (Map Unit #): Canutio-Nickel-Cajon Families Association (3026)

Percent of Basin: 25

Description of Major Soils (Percent of Mapping Unit):

1. Canutio Family (40) gravelly coarse sandy loam, 2 to 4% slopes (loamy-skeletal, mixed (calcareous) thermic typic torriorthents
2. Nickel Family (30) gravelly sand loam, 2 to 8% slopes (loamy-skeletal, mixed, thermic typic calciorthids)
3. Cajon Family (15) loamy fine sand, 2 to 8% slopes (mixed, thermic typic torripsamments)

Basin: Valley of Fire Wash

Soil Map Unit (Map Unit #): Sandstone Rock Outcrop (3074)

Percent of Basin: 10

Description of Major Soils (Percent of Mapping Unit):

1. Sandstone rock outcrop (85)

Basin: Valley of Fire Wash

Soil Map Unit (Map Unit #): Typic Torriorthents - Elvada - Yessum Families Association (3046)

Percent of Basin: 10

Description of Major Soils (Percent of Mapping Unit):

1. See description for Echo Bay

APPENDIX E

Stiff Diagrams of Principal Ionic Constituents in Soluble Eolian Material Composite Samples

1. Table of results of Analyses
2. Stiff Diagrams of Soils

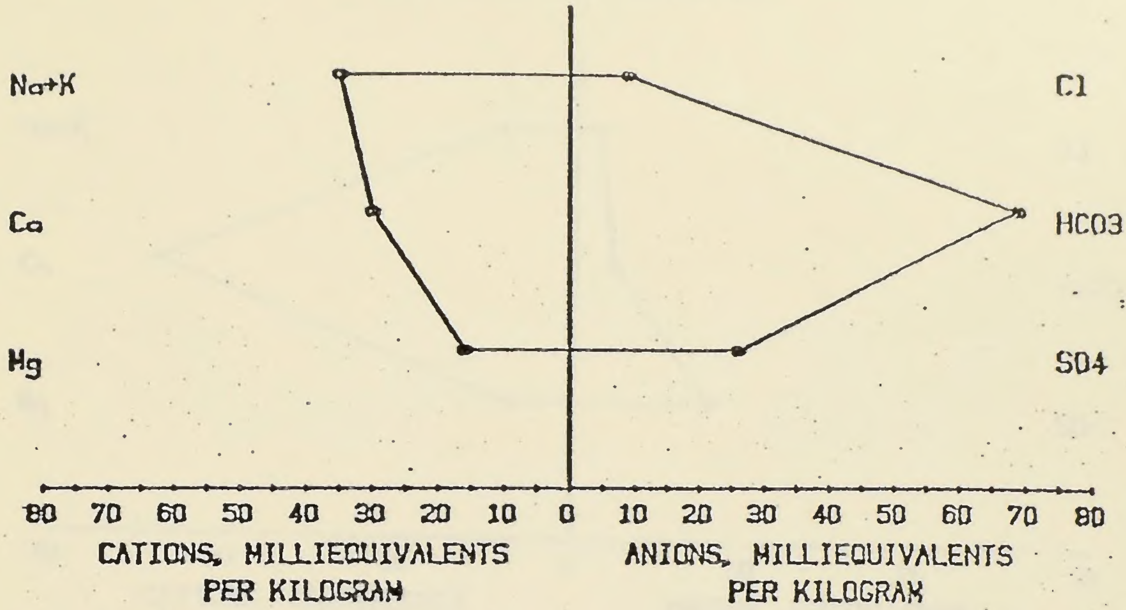
Table E-1: Chemical Analyses of Eolian Material Collected at Dust Collection Transects

Basin	Zone of Accumulation	Composite Sample #	Weight g	Soluble Material mg/kg	major constituents, mg/kg						T. Alkalinity as $CaCO_3$	DS samples combined
					$SO_4^=$	Cl^-	Ca^{2+}	Mg^{2+}	Na^+	K^+		
Government Wash	I	1	41.7030	4470	1264	317	611	195	391	705	8115	101,102,104, 105,106,110, 111,112
	II	9	5.5932	2735	1484	429	429	111	1108	77	1716	107, 108
	III	11	0.0348	1574712*	382184	45977	482759	48563	80460	41954	261494	109, 103
West End Wash	I	2	3.9549	40760	7004	1719	1183	743	1666	10948	94906	201,205,206
	III	8	5.2567	7514	3995	457	604	190	761	801	5117	203,204
Echo Wash	I	3	42.5234	4129	1112	198	376	181	484	600	1693	301,302,305, 307,308,311, 312
	I	4	20.6685	4311	1292	319	881	217	513	968	1650	317,306
	II	7	8.6679	1754	658	69	295	115	323	57	277	303,304,314
Valley of Fire Wash	I	5	13.0105	2152	1614	246	922	215	2706	92	2214	401,402,405, 406
	II	6	24.0692	3748	1122	58	1359	149	151	58	399	404
	III	10	21.7622	3207	2725	147	708	170	252	136	441	403

*Field notes do not indicate contamination. Values appear extremely high and are considered lab error due to the small weight of sample.

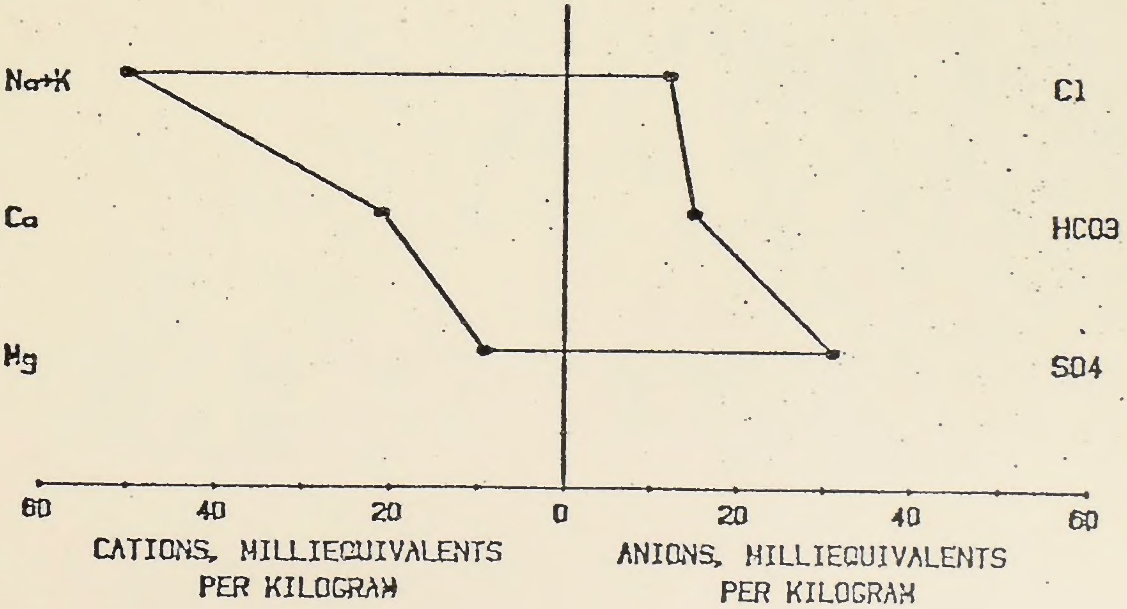
GOVERNMENT WASH
Zone I

COMPOSITE SOIL SAMPLE #1



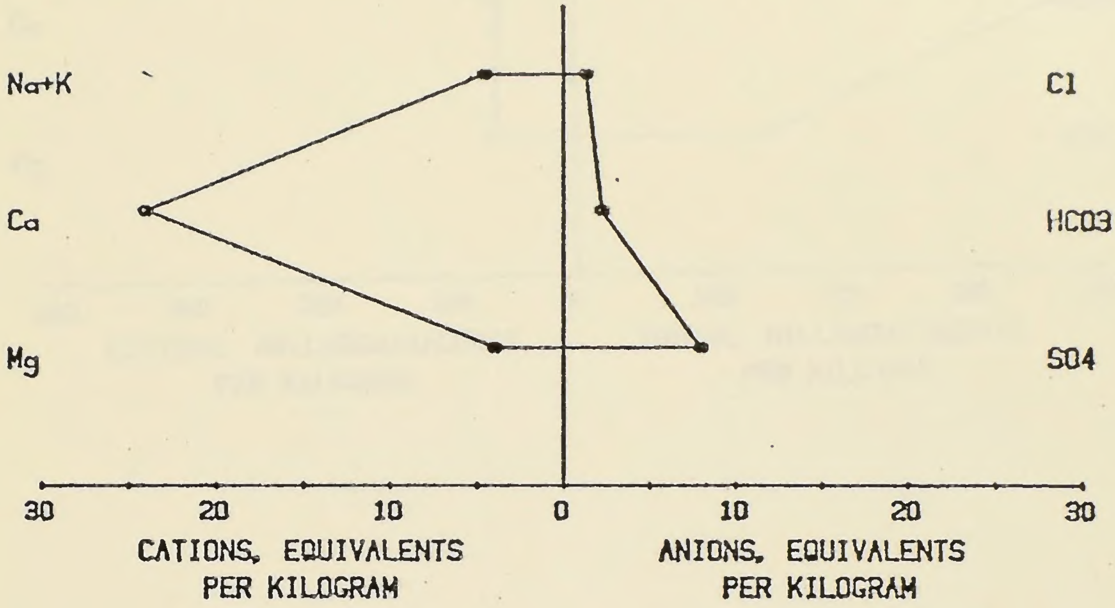
GOVERNMENT WASH
Zone II

COMPOSITE SOIL SAMPLE #9

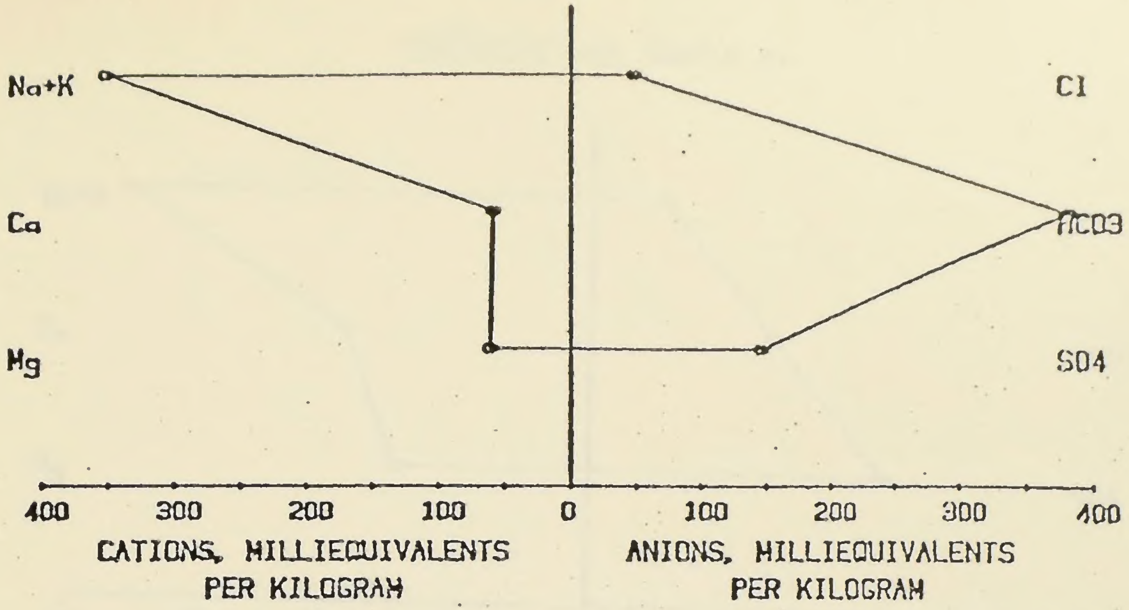


GOVERNMENT WASH
Zone III

COMPOSITE SOIL SAMPLE #11

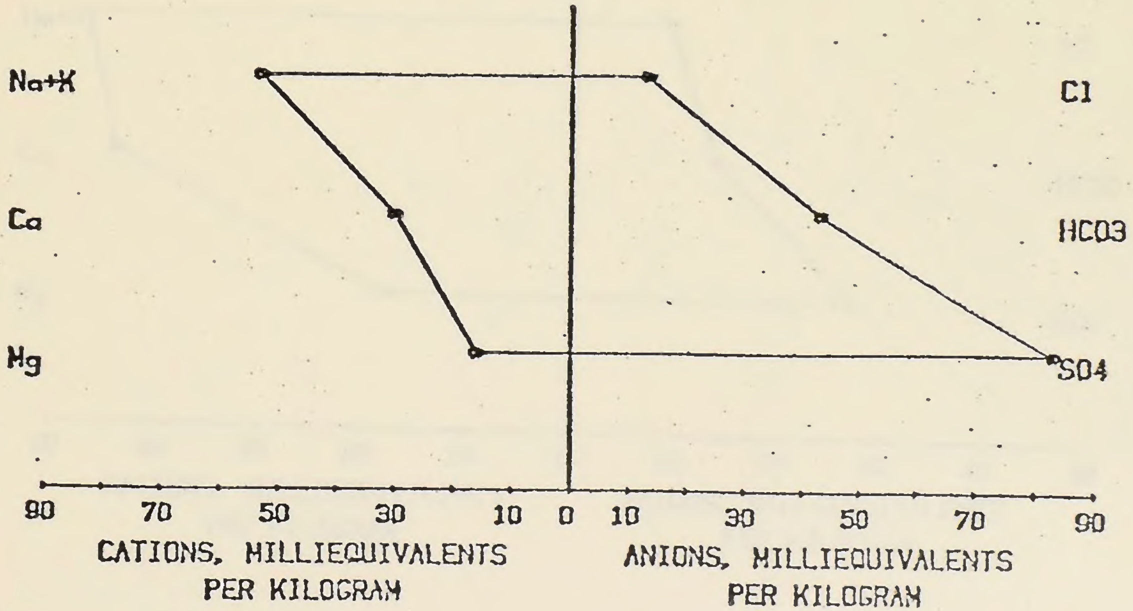


COMPOSITE SOIL SAMPLE #2



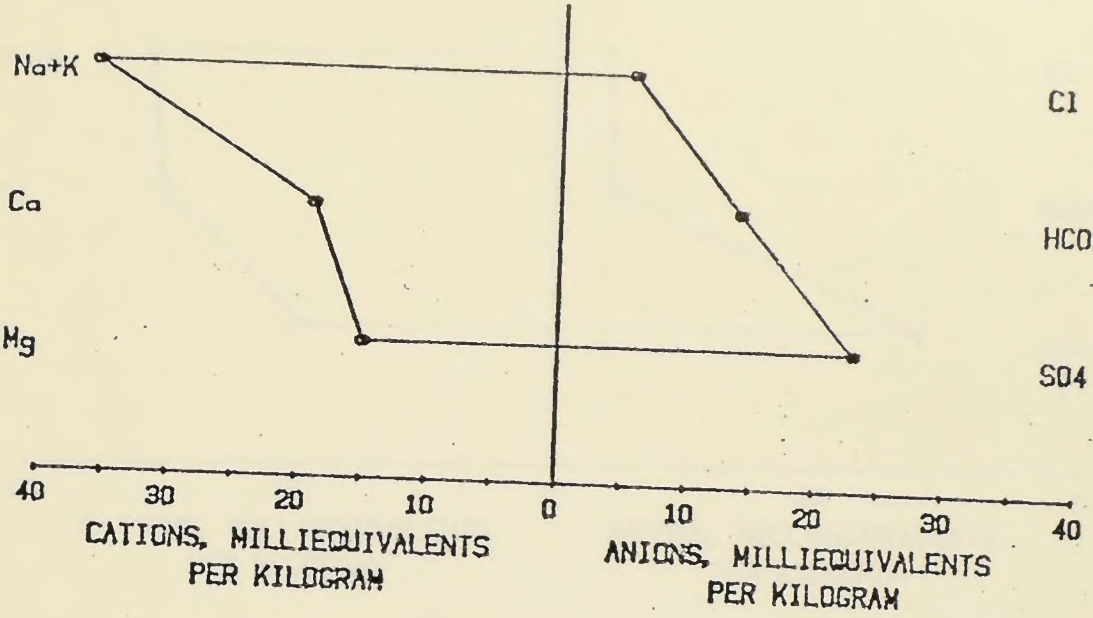
WEST END WASH
Zone III

COMPOSITE SOIL SAMPLE #8



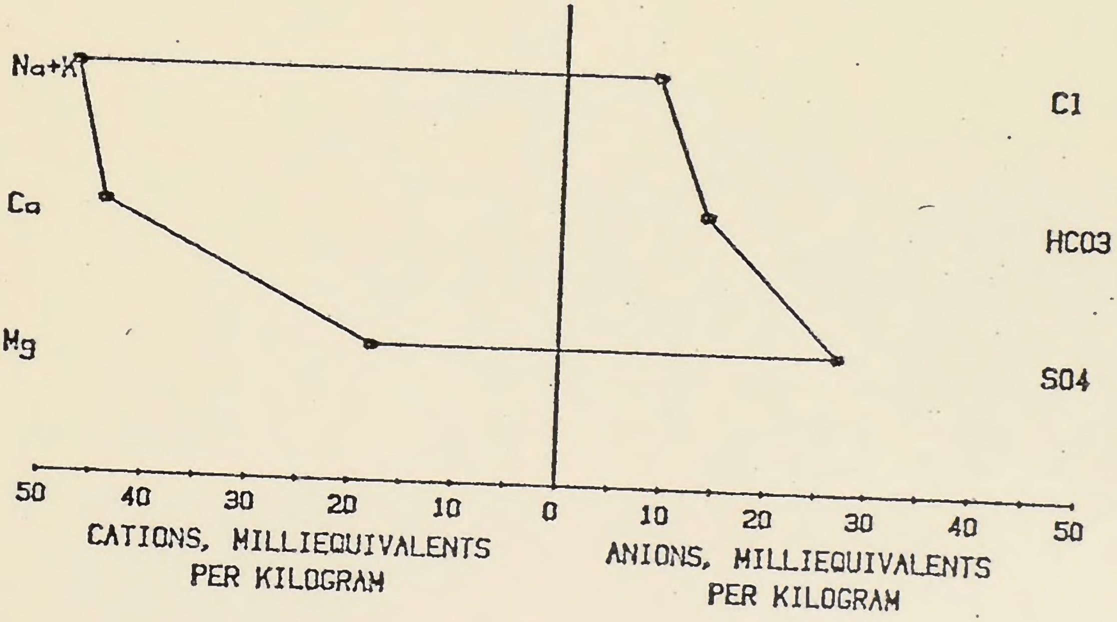
ECHO WASH
Zone I

COMPOSITE SOIL SAMPLE #3



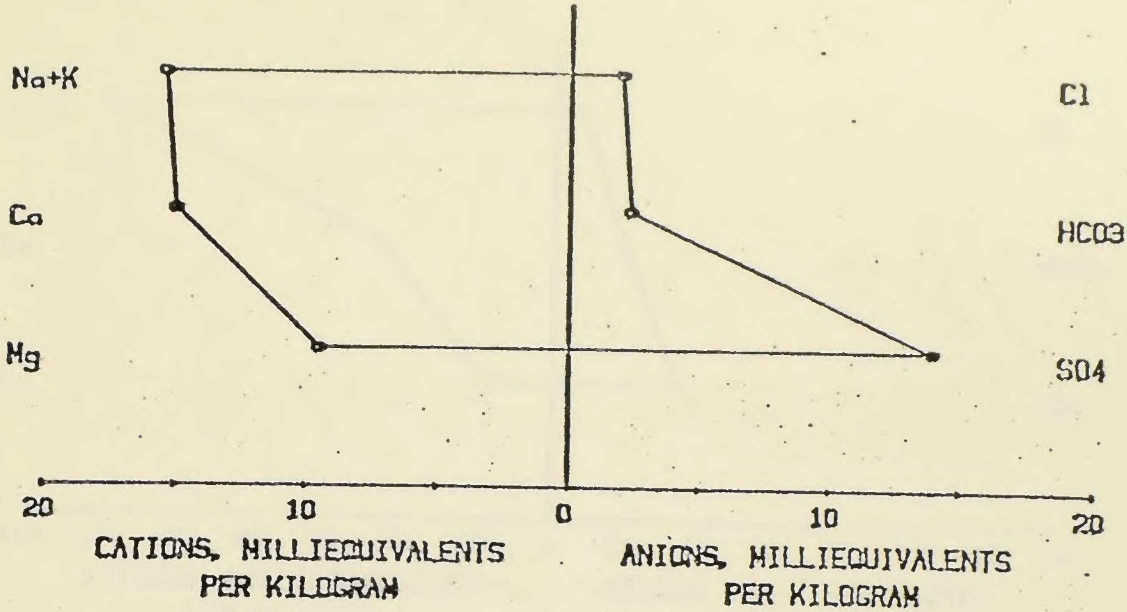
ECHO WASH
Zone I

COMPOSITE SOIL SAMPLE #4



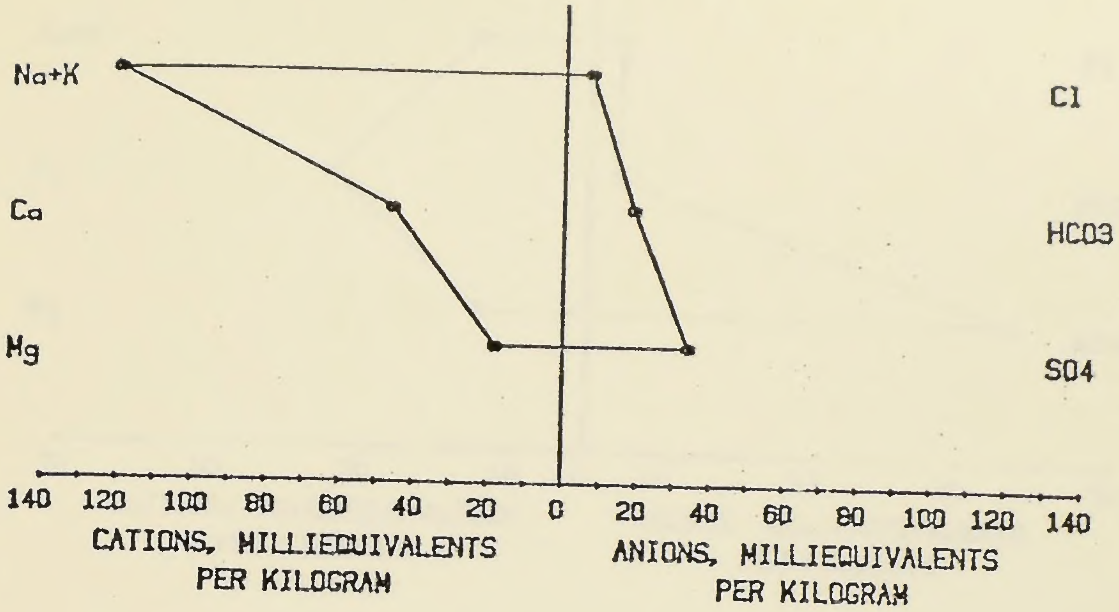
ECHO WASH
Zone II

COMPOSITE SOIL SAMPLE #7



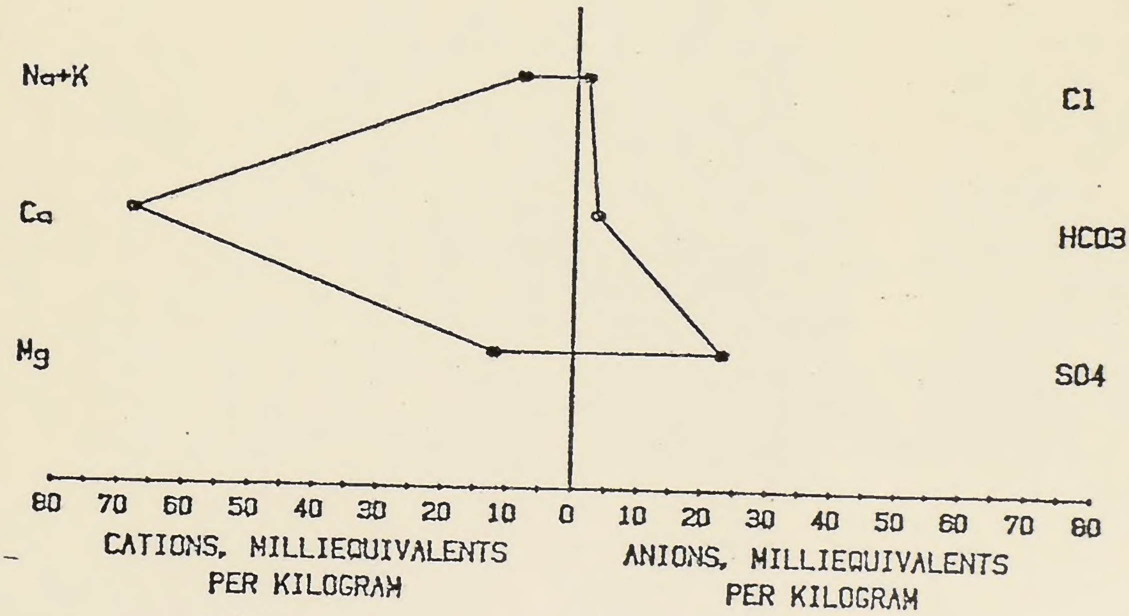
VALLEY OF FIRE WASH
Zone I

COMPOSITE SOIL SAMPLE #5



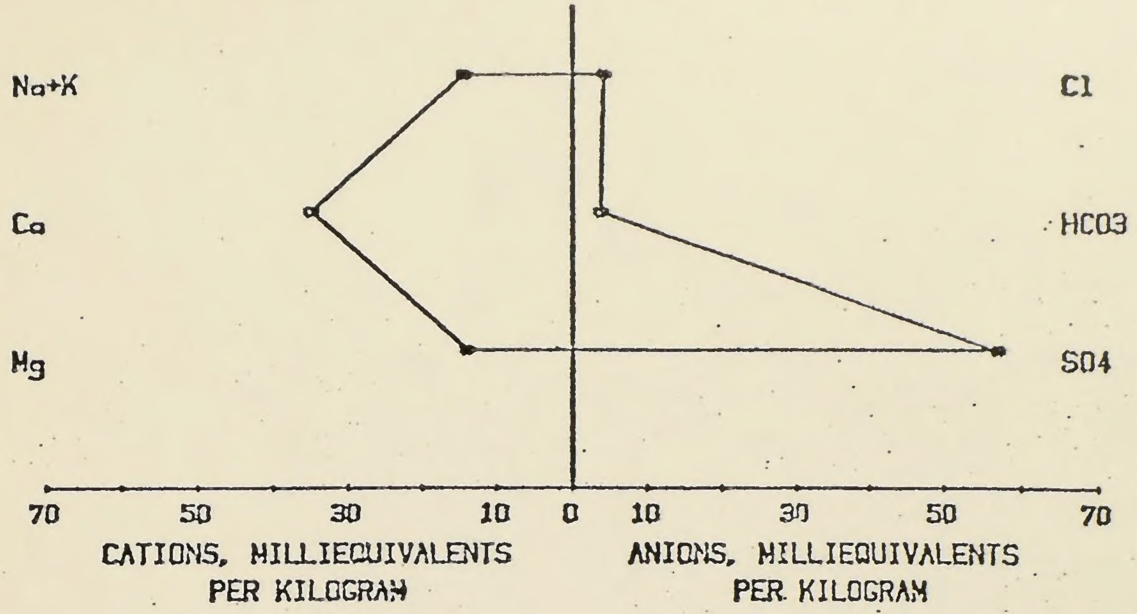
VALLEY OF FIRE WASH
Zone II

COMPOSITE SOIL SAMPLE #6



VALLEY OF FIRE WASH
Zone III

COMPOSITE SOIL SAMPLE #10



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